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Annual Survey of Engineering Progress

MISSISSIPPI FLOOD CONTROL

GEN. LYTLE BROWN
Chief of Engineers
U. S. Army

LEVEE CONSTRUCTION

GEN. THOMAS H. JACKSON
President, Mississippi River Commission

CHARLES S. HILL
Associate Editor
Engineering News-Record

BOULDER DAM TODAY

Economic Factors
DR. ELWOOD MEAD
Commissioner
U. S. Bureau of Reclamation

Technical Phases
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An Editorial Appraisal of Current Changes

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Construction Volume and Prices

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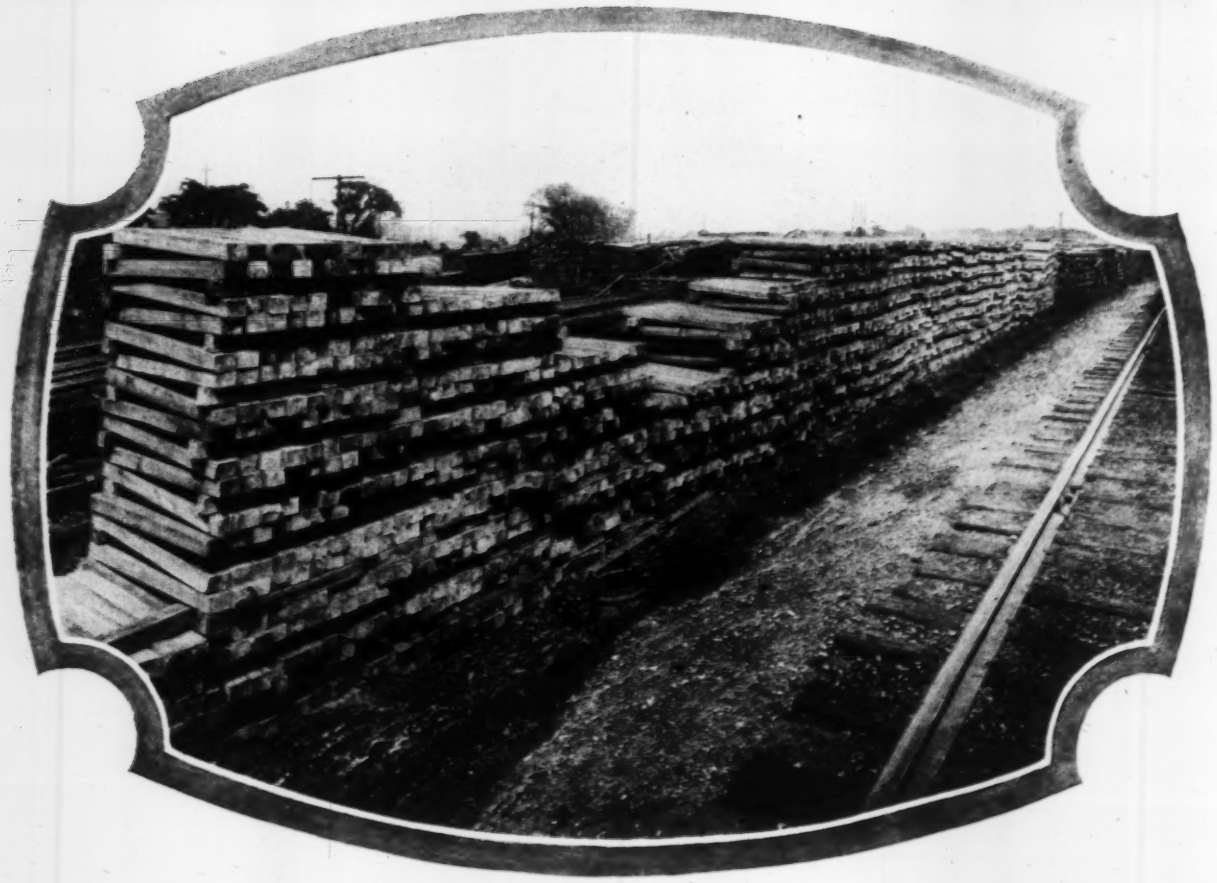

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DEVOTED TO CIVIL ENGINEERING AND CONTRACTING

F. E. SCHMITT, *Editor*

Volume 104 NEW YORK, FEBRUARY 6, 1930 Number 6

A Survey of Engineering Progress, 1929-1930

Foreword

IN SETTING his course the wise engineer looks about from time to time; he orients himself by backsight on the course just ended, observes the lay of the land, and adjusts his foresight accordingly. For assistance in this process the present summary of review and prospect in the fields of civil engineering and its related interests has been prepared.

At this time, however, correct orientation involves more than the normal work of the engineer. Two public works of transcendent character are in progress. History affords nothing comparable to the Mississippi flood-control enterprise and the Colorado River project. They are in their critical early stages just now, and constitute the foremost subjects of thought in the whole range of civil engineering. For this reason their planning and their controlling technical phases are discussed authoritatively in four articles in this issue.

General Lytle Brown, who took up direction of the Mississippi work at a time when its basic element was attacked in court, writes a remarkable statement of the thinking on which the project is founded. It will have the appreciation of the whole profession. General Thomas H. Jackson and Charles S. Hill supplement it in essential manner by an outline of present levee operations.

Dr. Elwood Mead, virile septuagenarian head of the Reclamation Bureau, tells the inwardness of the Colorado River question. Raymond F. Walter, chief engineer, adds a succinct statement of the technical problems involved. At the present moment the subject is involved in new controversy, but there is strong likelihood that contracts will be signed within a week or two and that thereby the work which, as Dr. Mead sets forth, means the future growth and well being of the West will enter the state of construction.

Business Stability Continues

FOLLOWING on a year of high though not record-breaking activity marked by a few surprising checks, the new construction season now opening is veiled in less than the usual amount of that uncertainty which must always attend the future. Enough light is thrown upon it by the events of 1929 and by the business budgeting which it inspired to make the prospect distinctly fair.

As to affairs in general, both the political world and the business world were unusually peaceful during 1929, with the effect of improving international credit and trade. In our own country production as well as trade remained well in line with the high level built up during the six or seven preceding years since the 1920-22 readjustment, and continued the increase made in 1927 and 1928. Though some lines showed decreases, others reached new high marks, and on the whole more commodities were manufactured, more wages were paid, more freight was moved, than in 1928. Prices kept an even level, due as much to present-day business principles as to competition. Our financial establishment gave remarkable account of itself, for when the inflated stock market broke down in October and November, disarranging credit and checking production and trade, the banking system came through unharmed. What is even more noteworthy, credit at once became freer than before the collapse.

Business and finance thus are in a state of health that warrants a highly favorable outlook for the coming year. It will be active; it will probably not set new records, but it will be sound.

The Construction Budget

CONDITIONS in the construction field lead to much the same conclusion. In 1929 construction had two unpleasant experiences. First came a sharp contraction of home building, beginning as early as February and continuing almost to the close of the year. It resulted from tightening credits for building, due in turn to the attractiveness of stock speculation. In amount it reduced the year's construction expenditure by nearly a billion dollars, in spite of small increases in public works. Later came the stock market collapse, and while this was potentially favorable to construction by freeing investment money it caused alarm and uncertainty for a time. Through all this, however, prices and labor conditions remained stable, indicating that no unfavorable internal factors are present in the construction industry.

Budgets for 1930 construction were set up and assembled earlier than usual, under the stimulus of a call from the President aimed at eliminating the uncertainty which follows a financial crisis. Even before the results of this call were in hand, a canvass of projected public work by *Engineering News-Record* (published Nov. 28,

p. 836) brought to light totals fully equaling those of 1929. Subsequent announcements of railroad, utility and industrial construction budgets show equal or greater expenditures here also. Private building, though not amenable to similar advance calculation, depends so closely on freedom of money as to give ample support to the forecast of a volume of work proportionate to the rate of growth in 1927 and 1928. In all fields construction activity will be helped by the improved bond market.

Planning for the future is sound only if based on a wider perspective than that of a season or a year. The long-range view is well outlined by Secretary Lamont, of the Department of Commerce, who says: "It is impossible to forecast what temporary ups and downs may occur; but the nature of the economic development of the United States is such that one may confidently predict, for the long run, a continuance of prosperity and progress." The post-war period of high productivity and stabilized distribution of income which has continued without break for seven years promises to endure; at least there are no present indications of its breakdown.

Events and Changes

FORTUNE has smiled upon the engineering world during the year. No major catastrophes occurred; windstorms caused no great destruction; and floods were of minor importance. An earthquake off the Atlantic coast severed nearly a dozen transatlantic cables.

Two outstanding events, both man-made, mark the year: Bad foundation conditions caused the abandonment of plans for the proposed great flood-control dam in the San Gabriel Valley, above Los Angeles, after $3,000,000 had been spent on excavation; at Detroit and Mount Hope two nearly completed suspension bridges had to be dismantled because of misplaced confidence in an untried material, tempered wire.

Transportation made several notable advances. Germany scored doubly by successfully sending the "Graf Zeppelin" around the globe with only three intermediate stops and by lowering the transatlantic steamship record to less than five days with the newly completed "Bremen." As an offset to this triumph the sinking of the "Vestris," an apparently stable vessel, carried more than a hundred people to their deaths just off our coast under circumstances which throw serious doubt on the efficacy of present regulations for safety at sea. Aviation continued its rapid growth, a new era in transportation being inaugurated by the start of regular 48-hour air-rail service across the United States.

An engineer took his place as Chief Executive of the United States for the first time since the administration of George Washington. His first major problem came with the collapse of the stock market in November. He met the situation by initiating immediate fact-finding concerning the industrial and construction programs of the country, a step which helped in averting a widespread loss of confidence. Little other governmental progress was made, and the long-talked-of centralization of federal engineering in a public-works bureau or department seems to have gone to sleep.

Last fall engineers from all parts of the world gathered in Japan in a world engineering congress and a power conference. Several international meetings are scheduled for 1930. The international road congress will convene in the United States this year.

Business saw interesting developments in the consummation of many mergers and in the growth of investment trusts. Bank mergers were prominent. The United States Steel Corporation merged the Atlas and Universal cement companies. Industrial co-operation is moving forward in trade association activities.

President Hoover proposed a step for study which may be of long-time significance to the country: cession of all unreserved public lands to the states (all in the West), and change of the reclamation law to confine federal activity to stream storage.

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Weather Conditions

THE country as a whole suffered less from weather extremes in 1929 than in several other recent years. There were no great floods, though minor floods spread over a considerable area in the Southeast and the lower Mississippi basin. A Western drought was a more striking feature of the year. Along the Pacific Coast the annual rains were so long delayed last autumn as to cause much concern about both city supply and power storage. The drought extended even into the Northwest, noted for its abundant water supply. The city of Tacoma rationed power for a time until federal aid came from the aircraft carrier "Lexington," which for 30 days beginning Dec. 18 helped to supply the city electric distribution system. Forest fire damage was high. Los Angeles began to study the reclamation of sewage for industrial uses and also for replenishing groundwater supplies. Officials of both Los Angeles and San Francisco urged water conservation. Finally, in early December long-delayed rains brought relief, and thereafter rains were continuous for almost a month in many parts of the coast territory. These occurrences are giving impetus to the study of water conservation in the Far West, and may stimulate not only a study of water conservation but also more thorough rainfall and streamflow coverage as well as studies of flood protection the country over.

Mississippi River Floodways

CONSTRUCTION of the Mississippi River flood-control project is in a new phase, as compared with a year ago. A new Chief of Engineers was appointed. Almost simultaneously the situation was changed by developments relating to the bypass floodways. Contrary to previous expectations, steps were taken early in 1929 to enter on construction of the Boeuf and Atchafalaya floodways, two major sections of the project. Both were to be built—so the Jadwin plan intended and so President Coolidge had specifically ordered—without paying the owners of land in the floodways for the taking. Suits were started by landowners, and in December the first case, in the Boeuf, was decided against the government after a hearing rendered sensational by the testimony of army engineers that there would be no additional flooding of the land, followed by their admission on cross-examination that such flooding would occur. The decision means that the project will cost millions, perhaps hundreds of millions, more than the estimate; it also means that a wholly different economic basis is laid down for the planning of the floodways—width, location, detail routing and balancing against other flood-control means. As indicated by General Brown in his article on another page,

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the plans are being restudied. A proposal by the board of state engineers of Louisiana would eliminate the Boeuf floodway and provide reservoirs on the tributaries above it; it would also modify the Atchafalaya floodway.

Controversy developed also over the Bonnet Carré spillway, relating to location and design. Work here is going steadily on, however.

Boulder Dam Act Effective

ON JUNE 21, 1929, six months after approval of the Boulder dam act, the seven states of the basin had not ratified the Colorado River Compact, but as six had ratified the act became effective in accordance with its terms. Bids for power were called by the Secretary of the Interior soon after. Later he fixed 1.63 mills per kilowatt-hour equivalent of falling water as the price, the contractor to install machinery in government-built power houses. Numerous bids were received, two responsible bids being for all or part of the power. He also set a price of 25c. per acre-foot for stored water, taken below the dam; water from the reservoir direct would be charged also with the power equivalent, bringing its price up to about $1 per acre-foot. Thereupon states, districts and municipalities demanded that they be assigned blocks of the power (in some cases with the right to use or not use at will), and some of the basin states also demanded that the power price be raised so that the annuities to be paid Nevada and Arizona under the act would be increased and so that a substantial surplus fund (Colorado River fund) might be accumulated. This marching and countermarching has delayed final formulation and execution of power contracts. Since the latter is required by the act before work can begin, the project still awaits the final step. Delay was contributed also by continued demands of Arizona that California limit its water appropriation from the Colorado, under threat of litigation; a final conference of the two states on this matter began two weeks ago (Jan. 20). Secretary Wilbur of the Interior Department has stated that he would act on the power contracts early in February. If he acts, appropriation of money by Congress will permit work to begin, as the Reclamation Bureau is preparing plans.

Structural Developments

STRUCTURAL thought is increasingly progressive. Its present tendencies continue in the forward direction marked out by the work of the past few years; constantly greater attention is being given to revising data and assumptions, applying more scientific methods and verifying design by research and by model analysis.

Buildings reaching up into new ranges of height are focusing earnest attention on lateral strength and stiffness. Research continues, though its results may be slow in coming. A photo-recording apparatus has been added to the wind-study equipment in the American Insurance Union Building, Columbus, Ohio, and similar equipment is planned for the Chrysler Building, New York City.

Active work on building code revision continues. The American Welding Society prepared a structural welding code and a group of definitions, symbols and nomenclature. Weld-test methods were extended to include X-ray apparatus and the stethoscope.

Problems brought forward by large bridges are laying strong emphasis on the advantages of model study and analysis. Measurements on a brass model of the 1,675-ft. Kill van Kull arch recently revealed important facts on the action of swaybracing. Model studies were utilized to good effect also in the investigation of the failure of a leaf of the Hackensack River bascule bridge on the Lincoln Highway.

Several sensational accidents, including the one just noted, gave impetus to study of structural phenomena that are usually ignored. Failure of several hangers formed of 18-in. I-beams in the new Tacony-Palmyra tied-arch highway bridge emphasized the danger of synchronization of wind pulsations with beam oscillations. A far more significant accident was the failure of hardened and tempered wires in the Mount Hope and Ambassador bridges, which raised questions concerning the metallurgy of wire manufacture that still are unanswered.

In research, a high point of recent work is the Port of New York Authority's study of large built columns. Important results concerning concrete-arch action were contributed by model studies at the University of Illinois, deflection tests on the Yadkin River bridge in North Carolina, and stress measurements by the Georgia highway department during construction of one of its bridges.

Materials of Construction

PROGRESS in materials of construction is not markedly active, but several developments were recorded in 1929. Carbon-manganese steel shapes and rivets were substituted respectively for the originally specified nickel steel shapes and ordinary carbon steel rivets in the Kill van Kull arch bridge. Discussions of stronger steel than the present structural grade for regular service have not progressed to any conclusion. Nirosta steel, a new non-corrosive and non-tarnishable alloy developed in Germany by Krupp, was adopted for all ornamental metal work on the Chrysler Building in New York. A new heat-treated wire for suspension bridge cables developed alarming and unexplained breakages during spinning, and was discarded. Cold-drawn wire was manufactured for the Hudson River bridge with an ultimate strength of 240,000 lb. per square inch.

There is yet no accepted specification for high-early-strength portland cement. The much discussed new cement specification to take cognizance of high-early-strength portlands and to fix earlier test periods and higher tensile strengths also for normal portlands is still in committee. The new cement reference laboratory supported jointly by the federal government and the A.S.T.M. was inaugurated. The Southern Pine Association announced a plan whereby the purchaser can specify the moisture content of his lumber. A new specification for wood preservation was announced by the U. S. Forest Products Laboratory, which takes into account the dimensions of the timbers rather than relying solely on the amount of preservative retained per cubic foot.

New Construction Technique

THE advance of construction technique during the past year has kept pace with that of former years. The construction industry is now equipped and organized to handle any job at any reasonable speed desired.

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Several records in construction were made in the past year. Outstanding in building construction were the phenomenal records made in erecting the world's two largest buildings, the 925-ft. Bank of Manhattan Building and the 1,044-ft. Chrysler Building, both in New York City.

Remarkable records in placing concrete and earthfill were made on two dams under construction last year. On Pardee dam in California, 67,000 cu.yd. of concrete was placed in one month, and on the Saluda dam in South Carolina, 701,000 cu.yd. of earthfill was placed in a similar length of time, both performances attributable to excellent organization and equipment.

New construction methods were found in construction projects from coast to coast. In Seattle conveyor belts were used to remove spoil from grading operations on a project cutting down an entire hill. On the Suisun Bay bridge in California 81-ft. steel cylinders were used to form artificial islands through which concrete caissons could be sunk in the dry. Conveyor belts in tandem placed concrete in the huge Merchandise Mart Building in Chicago. An advance in steel bridge erection was found at Louisville, Ky., where the usual heavy and expensive erection travelers were replaced by special guy derricks. On the Calderwood dam in Tennessee exceptionally dry concrete was dumped in 4-yd. batches from special straight-side buckets to be tamped into place by electric vibrators. Special handling methods involving the use of conveyor belts arranged on a central tower like a chuting system were developed to place dry concrete in the Diablo dam in Washington.

Lining a small water tunnel simultaneously with driving was an accomplishment on the Waterville hydroelectric project in North Carolina. Circular-cell cofferdams of steel sheet piling were used in building the Deadman's Island dam on the Ohio River just below Pittsburgh, a revival of the scheme devised to raise the battleship "Maine" in Havana harbor.

Construction Machinery

IN THE field of construction machinery, the cumulative effect of many refinements rather than infrequent and unusual innovations in design is resulting in machines of greater efficiency and reliability. Manufacturers are realizing that ease of maintenance is essential. Moving parts are being inclosed, gears and drive chains placed in dirtproof oiltight housing, central lubrication systems provided. Such refinements in equipment design increase output. For the same reason more attention is being paid to the comfort of operators.

Specific equipment developments include the following: increase in bulk cement-handling equipment; introduction of inclosed gearing on a power shovel; increased use of small portable pumps direct-connected to air-cooled engines; introduction of new steel armoring and reinforcing systems for pavements; extension of weight-proportioning equipment to skip mixers and an increase in the use of weight proportioning on central mixing plants; addition of new safety appliances to hoisting equipment; successful use of truck mixers and concrete bodies during their first full year of operation; and extension in the use of diesel engine power.

Power Expansion

USE of power is growing consistently 6 to 8 per cent faster than population.

Water-power development in the West is slowing up at an increasing rate. New construction during 1929 was even less than in the preceding year, only 38,000 kw. being installed, as against steam-power additions totaling 113,000 kw. Yet even in such an extremely dry year as that just closed the percentage of hydro-kilowatt-hours remains high. In California last year hydro energy represented 72 per cent of the total generated. For the coming year, estimated additions to hydro power in the eleven Western states total 189,000 kw., steam additions 270,000 kw.

In the Eastern states the total capacity of the hydroelectric power plants under construction is unusually large. Including eastern Canada, the larger plants alone approach two million horsepower, among them Saluda in South Carolina, Safe Harbor on the Susquehanna, Chat Falls on the Ottawa, Chute-a-Caron on the Saguenay, and Beauharnois on the St. Lawrence.

Reconstruction of old water-power plants continues to be a factor in power development presenting many interesting problems. At Spier Falls, N. Y., where increased flow due to regulation of the Hudson River makes more power available, a new unit is being added to the old plant. The runner is the largest in physical dimensions yet built, although the output will be less than some higher head units of smaller dimensions.

Natural Gas

THE year 1929 brought a new aspect to the industrial power situation in territory within 200 miles or more of those oil fields that produce natural gas on a large scale. A period of natural gas conservation has arrived. Texas, Oklahoma and California now have laws restricting the waste of gas in oil-field operations. The California law, put into effect in the latter part of 1929, had an immediate effect in creating almost a scramble to develop markets and get gas distribution systems under way. At San Francisco the Pacific Gas & Electric Co. changed its steam generating plants from oil to natural gas. The Southern California Edison used in its steam plants more than fifteen billion cubic feet of gas, the equivalent of three million barrels of fuel oil. In sharp contrast to earlier years of steam-plant operation, the fuel oil burned in plants of this system in 1929 was less than 1 per cent of the oil that would have been required if natural gas had not been used.

Dams

THE movement toward greater safety in the construction of dams which developed following the failure of the St. Francis dam is beginning to show its effect. Construction of the San Gabriel dam of the Los Angeles County Flood-Control District was abandoned during the latter part of the year, after three million dollars had been spent upon it, because of the unsatisfactory condition of the rock exposed in excavating for its foundation. Another dam farther down the same canyon, Pasadena's Pine Canyon dam, is to be built with special provision against possible damage from earthquakes. In the case of a high multiple-arch dam which developed some pronounced cracks in its abutments, the Lake Pleasant dam in Arizona, the spillway crest has been cut down in order to reduce the head on the dam and so insure its greater safety.

On the other hand, the movement toward added safety

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has not checked the construction of high dams other than the San Gabriel dam. The Owyhee dam, the highest yet built, is well along toward completion and the start of construction on Boulder dam, a still higher structure, awaits only the letting of contracts for the power which it will develop.

Waterways

COMPLETION of the system of locks and dams on the Ohio River and the opening of the river to slack-water navigation throughout its entire length was the most important development in inland waterways during the year. Vessels of 9-ft. draft may now operate from the Pittsburgh district down the Ohio and Mississippi rivers to New Orleans. The Illinois waterway, as a link between the Great Lakes and the Mississippi systems, is at a standstill, the State of Illinois having spent all the funds raised for its construction without completing the work and the War Department not yet having decided to take the waterway over in response to an appeal to complete it as a federal project.

Opening of the new Welland Canal from Lake Erie to Lake Ontario is scheduled to take place this summer, thus making it possible for large lake boats to come down to the head of the St. Lawrence River; but opening of the St. Lawrence to make it possible for these same vessels to go on down to Montreal seems now to be as far as ever from being undertaken.

Outside of the Ohio-Mississippi system the matter of internal waterways is not beyond the talk stage, in spite of President Hoover's known partiality to the development of such systems. Little change has occurred in the traffic carried on the existing modernized waterways, but the opening of the Ohio promises to bring an increase in that region.

Panama Canal traffic is continuingly heavy. Studies for the new reservoir on the Chagres to increase the capacity of the canal are progressing. Nicaragua canal surveys by a Corps of Engineers party are not yet completed.

Railway Electrification

RAILWAY electrification work has been pushed actively during the year. During the latter part of 1928 the Pennsylvania Railroad announced plans for the electrification of its principal lines on the Atlantic seaboard as a continuation of the electrification work then in hand between Philadelphia and Wilmington. Extension of the Philadelphia electrified zone eastward to Trenton is now under way. Indications are that electric operation will be carried through to the New York electrified zone soon. Electrification of the Reading Railway suburban lines at Philadelphia continues, and the present program will be completed this coming season. This company also is considering electrification of its line to New York and into the Pennsylvania coal regions. Electrification of the suburban lines at the Lackawanna Railroad at New York, begun in 1928, will be completed within about a year. Electric operation is to be applied to the tracks of the New York Central on the west side of Manhattan Island; a number of self-contained electric locomotives have been ordered for use on this line during the reconstruction period. Similar locomotives have been put into service by the Illinois Central at Chicago preparatory to abandonment of steam traction for freight service in its electrified zone.

New Railroad Construction

CONSTRUCTION of new railroad lines is active in parts of the country. The 1929 total (over 500 miles) falls behind that of 1928. Improvement of existing lines by double tracking, by line and grade revision and by the installation of automatic signals and train control is being pushed energetically. Large expenditures on new passenger terminals continue. The new terminal at Buffalo was put into use early in the year, and the new Union Terminal at Cleveland is expected to be in operation by the middle of the year. Already trains are being run into it. Work is progressing upon the Pennsylvania Railroad's large terminal reconstruction project at Philadelphia and upon the new Union Terminal at Cincinnati. Plans for major passenger terminal reconstruction projects at Newark, N. J., and at Baltimore, Md., by the Pennsylvania Railroad are under way.

Valuation and Consolidation

TWO events of widespread interest in the railway field in the year just past were rejection by the U. S. Supreme Court of the methods used by the Interstate Commerce Commission in determining the value of the St. Louis & O'Fallon Railroad—a test case in railroad valuation—and promulgation by the Interstate Commerce Commission of plans for consolidating all railroads into a few systems. How significant they will be remains to be learned. In the O'Fallon case the decision was negative, giving no rule for valuing. In the matter of consolidation, the commission's plan was announced only late in the year.

Utility Regulation

REGULATION of utilities tends more and more toward the greater protection of capital invested in them. In the Baltimore Street Railway case the U. S. Supreme Court stated that it is not certain that rates securing a return of 7½ or even 8 per cent on the value of the property would not be necessary to avoid confiscation. Also, the court advocated the use of methods of depreciation accounting highly favorable to the property owners. More recently a federal court in New York State set 7 per cent as a proper return upon the property of the New York Telephone Co.

The matter of determining the value of utility properties remains as much of a muddle as ever. In the Baltimore rate case the court declined to pass upon one important element of valuation work, and in the O'Fallon case the court did not say how reproduction cost new shall be used in valuing.

Active Bridge-Building

THE intense activity in bridge construction of the past few years continues. Increasing highway traffic calls for more bridges as it does for roads. Toll-refunding financing for bridges has proved itself. Definite progress was made on both the 3,500-ft. Fort Lee suspension bridge and the 1,675-ft. Kill van Kull arch. The first bridge across Lake Champlain, a public toll structure, composed of a series of continuous trusses, was opened to traffic. A

vehicle roadway was added to the Quebec cantilever railway bridge. The 1,097-ft. cantilever of the Montreal-South Shore bridge was closed.

Two private toll bridges, the Cooper River crossing at Charleston, S. C., a structure 14,000 ft. long involving a 1,050-ft. cantilever span, and the Tacony-Palmyra 550-ft. steel arch bridge over the Delaware River at Philadelphia, were opened in August. Work on the 1,200-ft. cantilever over the Columbia River at Longview, Wash., progressed so that early closure is expected. One of the important toll-bridge developments of the year occurred in California, where the state highway commission sponsored a proposal to the legislature to require all toll bridges to be state owned and financed by income bonds—a type of security used successfully by the Port of New York Authority and utilized by the city of Louisville in constructing its new Ohio River bridge which was opened on Oct. 31.

In the field of railway bridges, the most important developments were the beginning of construction work on the Southern Pacific's Suisun Bay bridge near San Francisco and the completion of the Big Four's Ohio River crossing at Louisville.

Suspension bridges are coming into increasing prominence. Late in 1929, the 1,850-ft. Ambassador bridge at Detroit was opened, after being dismantled and re-erected; the 1,500-ft. Poughkeepsie bridge advanced to the stage of cable spinning; the Mount Hope bridge was opened to traffic after being dismantled and re-erected; a 785-ft. span at Toledo was placed under construction; a 1,207-ft. span with wire-rope cables was begun in Portland, Ore.; and a highway suspension bridge of 880-ft. span was completed over the Royal Gorge in Colorado some 1,100 ft. above the Arkansas River. The Grand Canyon suspension bridge was rebuilt. Bids have been asked on a Y-shaped structure 17,710 ft. long to connect Manhattan, Bronx and Queens boroughs in New York, involving a 1,380-ft. suspension bridge. Several other suspension bridges are planned.

Buildings Attain Colossal Dimensions

A CONTINUED trend toward taller buildings is reaching into the range of the colossal. Basically resulting from high land values, this trend has been given impetus by the advertising urge or vanity of individuals and corporations. Continued development in the tall-building field is in sight. The trend is shown by the past year's achievements.

In New York City the 792-ft. height of the Woolworth Building was exceeded twice, by completion of the Chrysler Building, 70 stories, 1,044 ft., and the Bank of Manhattan, 70 stories, 925 ft. The Empire State Building, 85 stories, 1,050 ft., is being started. High buildings announced for construction are: City Bank-Farmers Trust Co., 71 stories, 925 ft.; 42nd St. and Fifth Avenue, 58 stories; Hippodrome Building, 83 stories; Columbus Circle, 65 stories. In Pittsburgh the Gulf Refining Co. has announced a building 575 ft. high. The United Shoe Machinery Co. has completed a 27-story building in Boston. In Chicago the 45-story office building housing the new Civic Opera auditorium, the 26-story Daily News Building—the city's first large air-rights office building—the Palmolive Building and the Carbon & Carbide Building are notable. Detroit built the 40-story Union Trust Building, its second tallest. Three tall buildings of reinforced concrete were completed: the 26-story 310-ft. Victory Building in Toronto, the 23-story 277-ft. Exchange Building in Seattle, and the 19-story 264-ft. Medical Arts Building in Minneapolis.

Sizes as measured in volume are also growing to huge dimensions. The Chicago Merchandise Mart, inclosing 53,000,000 cu.ft. within its eighteen stories, nearing completion, will be the world's largest. The 85-story Empire State Building in New York is a close rival, its base dimensions being 200x425 ft. An airship dock in Akron, 325x1,200 ft., with arch trusses 200 ft. high, is notable.

Welding of building frames is advancing. Work is started on a twelve-story structure for the Southern California Edison Co. in Los Angeles, with lateral bracing arc-welded. A 300-ton gas-welded mill-type building was erected in Niagara Falls, N. Y.

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Highway Trends

ROADBUILDING sees no check ahead. In fact, demands are increasing, and the federal-aid contribution will probably be increased two-thirds by Congress.

The record of road construction was maintained in 1929. No figures including county and township roads are obtainable, but in state roadwork the record was about 20,000 miles surfaced and almost 9,000 miles graded to engineering standards. But trends in public roads development are better expressed in taxation and financing, legislation and traffic service.

Gasoline taxes have been increased, and the increase in large part has been distributed to counties. A new peak in maximum rates was reached by the 6c. tax imposed in three states. In all but seven states the counties now receive some portion of the gasoline tax. Other means of financing exhibit no distinctive change. Traffic service presents a turn of thought to arterial and special service roads, to roadside improvement, to wider rights-of-way, to guiding and safeguarding traffic.

The trend in road types has not greatly changed in character, but the year has witnessed greater emphasis of low-cost roads and also the beginning of a movement to requisition government aid for local roads. National highway legislation saw little activity. States continue to urge a toll-bridge law which will give them better protection in interstate toll-bridge promotion.

Traffic Congestion

PROBLEMS of traffic congestion and control continue to multiply and become more complex. In all metropolitan districts a continuous program of rerouting and speed regulation has gone on in an effort to reduce delays which are becoming an increasing expense in the movement of goods and people. As these activities are not meeting the demands, reorganization of road systems is recognized to be the task immediately before communities wherever population is concentrated. About the larger cities the problem is being considered as regional and whole groups of municipalities are being co-ordinated into a regional road system designed as a co-operative undertaking. In all communities, large and small, wherever relief to traffic is being sought by reorganizing road systems, the pressing question is finance. System reorganization is expensive and local tax burdens are such already that road officials shrink from subjecting their programs to the risk of popular revulsion against continuing high-

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way expenditures. To meet the difficulty they are casting about for state aid as a means of escaping a local duty which promises discomfort. Outside of the metropolitan areas highway congestion is limited to main trunk highways and is being met by increased widths or the improvement of alternate routes. In general there is road room enough on rural highways; improvement of surface is the greater traffic requirement.

City and Regional Engineering

IN SCOPE and complexity municipal engineering is increasing rapidly. Needs for more and better streets and paving, water supply, sewerage, grade-crossing elimination and bridges are becoming more urgent within every city and village of the land. Our cities having overflowed into the surrounding country until it has become urbanized for miles in all directions, city engineering is rapidly becoming regional engineering.

Governmentally few of our cities are organized for comprehensive correlated planning and building of public works, however admirably each class of works may be handled separately. The case is far worse for regional planning, the regions seldom following either city or county lines and often including all or parts of a score or more of cities and two or more counties.

Recognition of the need for comprehensive and correlated engineering, both city and regional, is shown by the existence of six to seven hundred city planning commissions and twenty to thirty regional commissions. Few of either are so integrated with local governing agencies as to make them more than recommendatory bodies. Conditions in this respect are improving.

The year saw the completion of the most notable studies in the broader field ever undertaken, resulting in a regional plan for New York and environs. Adoption of the various elements of the plan rests with the governing bodies of hundreds of communities, in three states. To promote such action, a regional planning association has been formed. Work on another regional problem, also embracing parts of three states, is in progress at Philadelphia. Planning agencies integrated with county government are doing good work centering in Detroit and in Los Angeles.

The newest single element in city and regional engineering is the provision of airports. The most extensive single line of construction is the widening and extension of major highways. Water supply, sewerage and park systems, the earliest examples of regional engineering, are also being enlarged. Refuse disposal also may become a regional activity.

City Transit

THE miles of track of street railways continue to decrease, but the loss in mileage, as in previous years, has been more than offset by the increased mileage of bus lines. The number of passengers carried by both means of transportation remains about constant, there being some increase in the larger centers and a falling off in outlying districts. Despite this the financial condition of the operating companies continues to improve. Modernization of equipment and the development of newer types of street cars have been important factors.

The development of new types of trackless trolleys has revived interest in that type of vehicle. The newer types are cheaper to operate than buses, have much of their flexibility and eliminate track and pavement maintenance costs. The use of buses in intercity transportation has not increased greatly.

Few cities have done much toward improving their rapid-transit facilities during the year. At Detroit a proposal to build the first units of a citywide rapid-transit system was defeated by the voters in the spring. Chicago is considering a plan. St. Louis has begun a new study for a rapid-transit system. Only in Philadelphia and New York has there been any considerable amount of new construction. In Philadelphia the extension of the Broad St. subway under South Broad St. is about ready to be put into operation. Part of New York's Eighth Ave. subway will be ready for operation in 1931.

Sewerage and Refuse

SEWAGE collection, as distinct from disposal, shows little change in sight. In sewage disposal the largest program is that of the Chicago Sanitary District, intensified in degree of treatment and speeded up in time by the decision of the U. S. Supreme Court that it is unlawful to divert water from Lake Michigan beyond a "negligible" amount. Subsequent findings by Charles E. Hughes, special master, if adopted by the court, will require "complete" treatment of the immense volume of sewage from the entire district by the end of 1938. Much to that end has been done and more is under way. Elsewhere the most notable sewage-treatment project is a large activated-sludge plant on Wards Island, New York City, for which preliminary plans were completed last year. The world over, the activated-sludge process is growing in use, but tank treatment is still the prevailing method.

Incineration of refuse is still gaining over other methods of disposal, the reduction process slowly losing ground. Federal court proceedings against dumping New York refuse at sea, to the alleged damage of New Jersey ocean bathing beaches, combined with the establishment of a New York Sanitation Commission, in charge of refuse and sewage disposal, have accelerated an incinerator-building program adopted by New York several years ago and already well under way. A dozen or more additional incinerators are proposed.

Water and Interstate Controversies

INTERSTATE controversies over water rights affect four large projects East and West. The U. S. Supreme Court has been asked by Connecticut to prevent Boston and adjacent cities from diverting water from the drainage basin of the Connecticut River, and by New Jersey to stop New York City from going to the Delaware River for water. At Chicago, the famous suit to prevent diversion of water from the Great Lakes to the Mississippi drainage basin rests primarily on an attempt to protect the local water supply from sewage pollution; the court has conceded the right to divert water for domestic supply but not for sewage disposal. The apportionment of the Colorado River water is still in dispute among the states involved, as outlined in Dr. Elwood Mead's article on another page.

The eastern part of the Boston metropolitan project is well on toward completion. New York City awaits findings of a master, just appointed by the court, and subse-

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quent court ruling before beginning construction on the Delaware project, but meanwhile it is making plans. Chicago is experimenting on water filtration with a view to designing works to treat its entire supply. The Southern California Metropolitan Water District, which includes Los Angeles and other cities, is continuing studies begun several years ago to determine the best route for an aqueduct from the Colorado River; a commission of noted engineers has narrowed 56 possible routes to four. Although Arizona has threatened resort to the U. S. Supreme Court if its views as to allocation of water stored by the Boulder Canyon dam are not met, it seems likely that by the time an aqueduct route has been chosen and plans and specifications have been drawn for the aqueduct from the Colorado River to Los Angeles some settlement of the dam controversy will have been effected. The proposed aqueduct exceeds in magnitude anything of the kind hitherto built.

Municipal Chaos at Chicago

A FAVORITE subject of speculation among those whose minds or pocketbooks are concerned with municipal expenditures is by what percentage these could be cut down by reducing—the more hopeful say by eliminating—inefficiency, extravagance and graft. The question has been repeated again and again during the recent and present financial débâcle at Chicago. A private corporation so deeply embarrassed financially as is Chicago today would have been put in the hands of a receiver months ago. Latest reports indicate that the program of the local relief committee trying to devise means to continue paying salaries and coal bills has proposed what in effect is a receivership, as regards the use of the money contributed to the relief pool by citizens and taxpayers. At this the city officials balk. Give up control of money expenditure? No! Yet a receivership for Chicago, financially, politically and morally, offers the only way out.

Contracting Progress

CONTRACTING activities were large in 1929, corresponding to the nine-billion-dollar construction program, but prosperity among contractors has not been commensurate with this great activity. Prices were generally low. Withal, the organized contracting industry has made progress in stabilizing its relation to other elements of the construction industry. It has improved practice in surety-bond writing by setting up with the surety companies a bureau of contract information which is fast putting on file the verified business and performance record of every general contractor. During the year distinct advance has been made in requiring the prequalification of contractors bidding on public works. Adoption of the practice has been most general in state highway construction, but a number of cities have taken it up and legislation permitting its general use is being urged in several states and has been enacted in one. Concurrent with prequalification there has been a tightening up by public works officials in after-the-bid investigation of the low bidder.

Credit stabilization has made progress, chiefly through the allied industries committee of the Associated General Contractors and a dozen specialized contractors' associations. While directed toward sounder credit and trade practices, this work had the secondary effect of improving the relations of general contractors and subcontractors, particularly in building construction. In the same line of harmonizing working relations, contracting associations are getting into closer touch with organized labor in agreements concerning jurisdictional strikes.

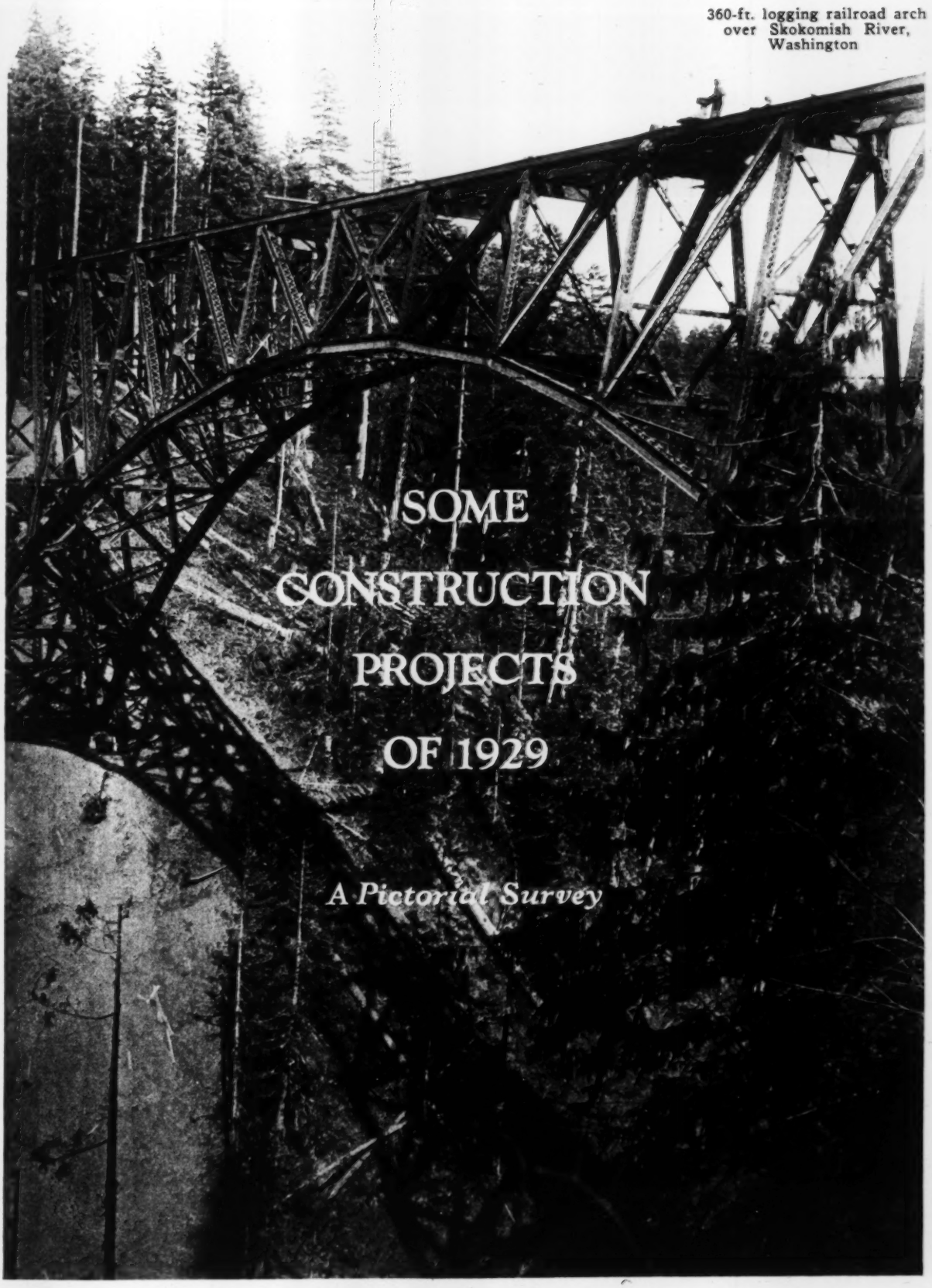
Association work, though one of the brightest elements of contracting, has not the wide support in membership and money that its importance warrants. Contractors' associations have been regarded more highly by other elements of the construction industry than by contractors. This condition is just now beginning to mend.

Air Transport Progressing Rapidly

THERE are now 458 municipal, 491 commercial airports and 282 intermediate landing fields in operation. During 1929 about $50,000,000 was spent on airport construction and some 110 new commercial or municipal airports were added. About 100 hangars and 30 to 35 administration buildings were constructed. Scheduled operation mileage totaled 24,874, against 19,254 in 1928. Scheduled miles flown was 16,000,000 in 1929, against 10,673,000 in 1928. It is estimated that unscheduled flying added 125,000,000 miles. In 1929 the daily schedule of flying was 79,570 miles. Passengers carried totaled 85,000, against 49,000 in 1928, and the 8,000,000 lb. of mail carried was just double the 1928 figure. Established airway mileage is now 35,000 against 16,000 in 1928. Plane production in 1929 reached 7,000 planes.

Outstanding developments of the year included: inauguration of air-rail passenger service and ship-to-shore mail service; large increase in paved runways; the Lehigh Airports competition; an unusual number of tragic accidents, although the mileage flown per fatality was about 25 per cent greater than in 1928; inauguration of South and Central American air routes by American companies; completion of the airship hangar at Akron and the start of construction on the "ZRS-4," the largest rigid airship yet undertaken; around-the-world flight of the "Graf Zeppelin" in 21 days 7 hours and 34 minutes; successful completion and test flights of the first metal-clad dirigible; heavier planes, capable of carrying up to 32 passengers; attempts by the aeronautics branch, Department of Commerce, to secure the support of the states in controlling and licensing intrastate air traffic; national airport conference at Cleveland in May and regional conferences subsequently in Bridgeport, Boston, Los Angeles and Atlanta, sponsored by the airports section, Aeronautical Chamber of Commerce; airport conference in Washington, sponsored by the city officials division, American Road Builders' Association; large increase in use of radio and of U. S. Weather Bureau facilities.

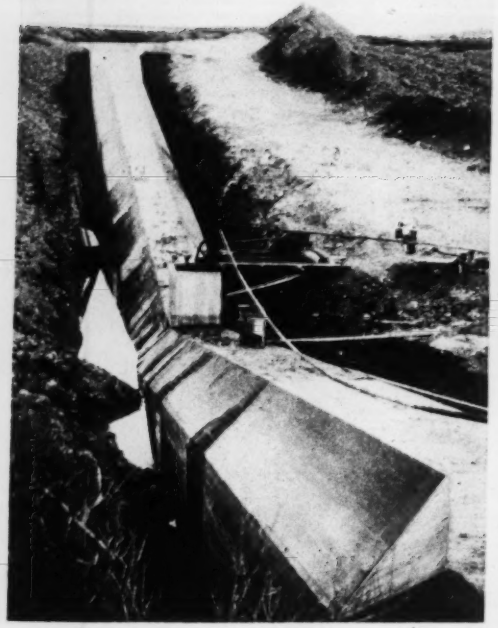
In spite of these developments, the aviation industry by the close of the year reached a state of severe depression. Plane-building plants shut down or curtailed operations. Passenger lines cut rates in many cases to nearly those of railway lines, an indication that the traveling public is still air-shy. Two or three unusually distressing passenger-plane crashes had a discouraging effect. The aviation industry and the government supervisory authorities probably increase the public shyness by their policy of secretiveness in matters of plane accidents. Flying safety is one of the big subjects for advance in 1930.



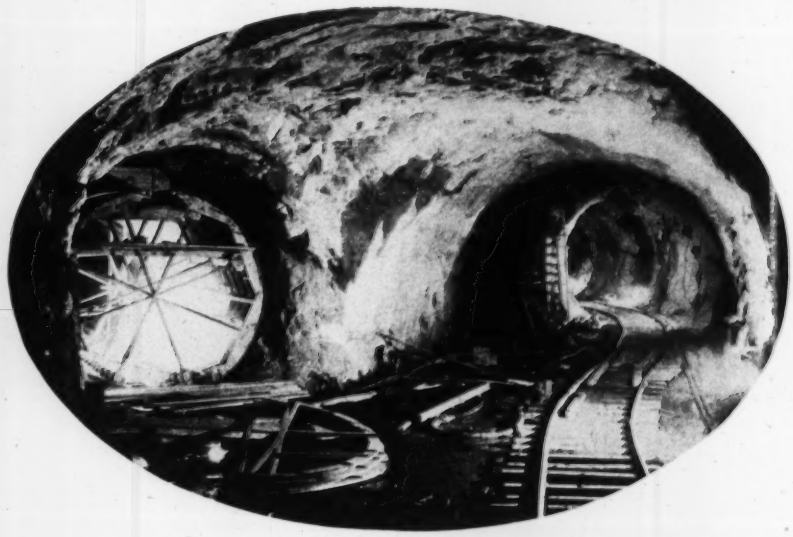
360-ft. logging railroad arch over Skokomish River, Washington

SOME CONSTRUCTION PROJECTS OF 1929

A Pictorial Survey



Above: Little Dry Creek siphon, one of 25 on Kittitas division, Yakima irrigation project, Washington



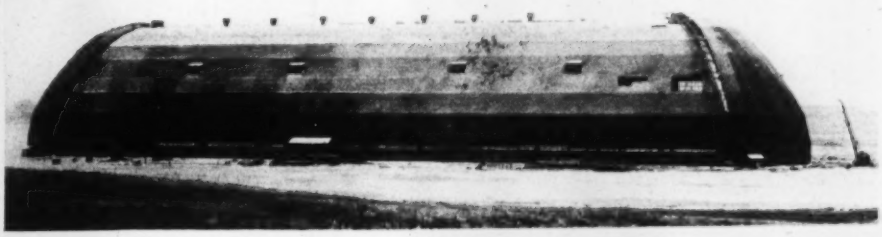
Above: Pressure tunnel penstock manifold, Calderwood hydro-electric project, Tennessee. Track shown is standard gage

Below: Highway suspension bridge, Royal Gorge, Col., 1,050 ft. above stream

Above: Pardee dam, Mokelumne River, Calif. Spillway structure in foreground

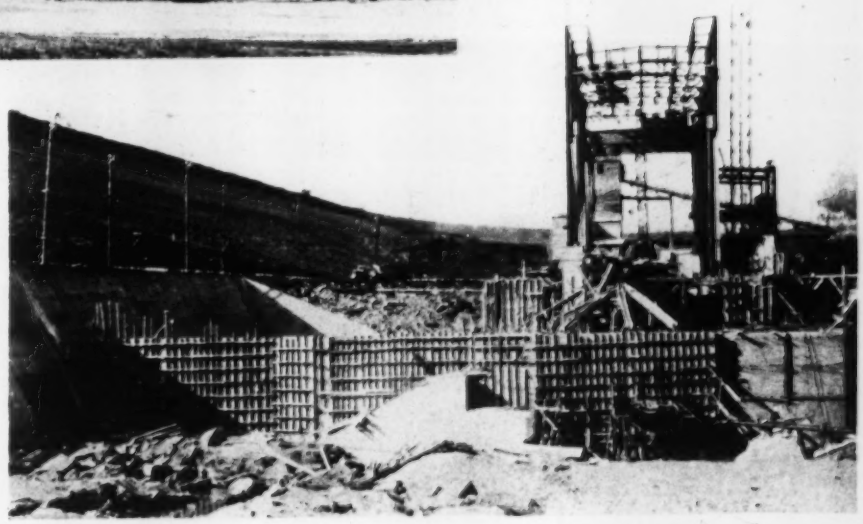
Below (Both pages): Washington concrete multiple-arch bridge, Seekonk River, Providence, R. I.

Above: Cable spinning on Mid-Hudson suspension bridge, Poughkeepsie, N. Y. Center span 1,500 ft. Suspended side spans 750 ft. each

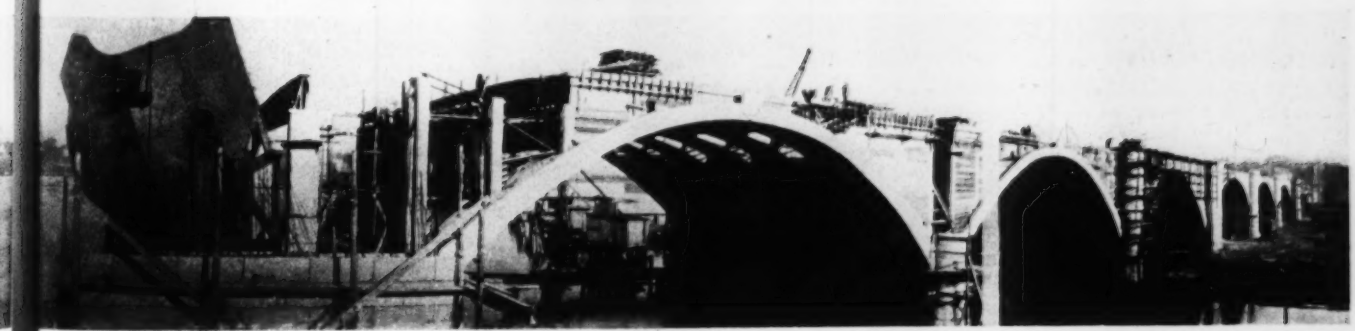


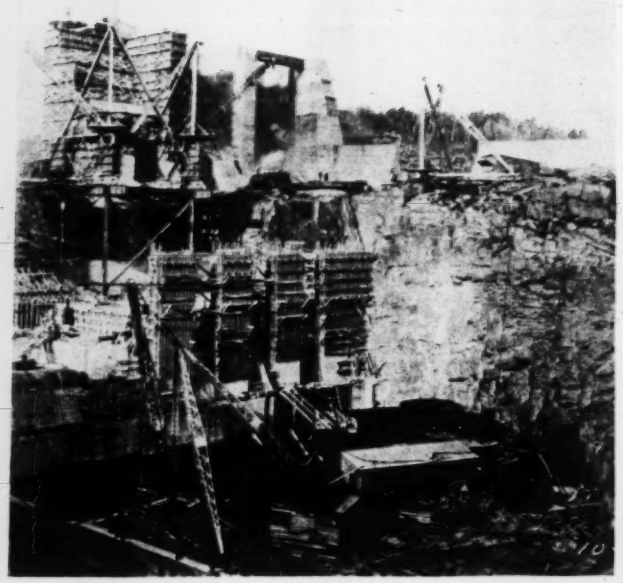
Upper left: Haddon Hall Hotel, Atlantic City, N. J.

Above: Goodyear Zeppelin factory and dock, Akron, Ohio



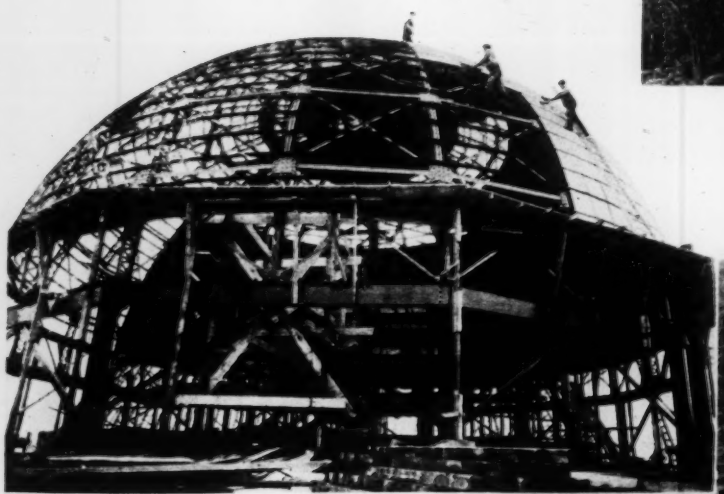
Right: Constructing power house, Saluda Dam, Columbia, S. C. View shows part of 11,000,000-cu.yd. hydraulic fill





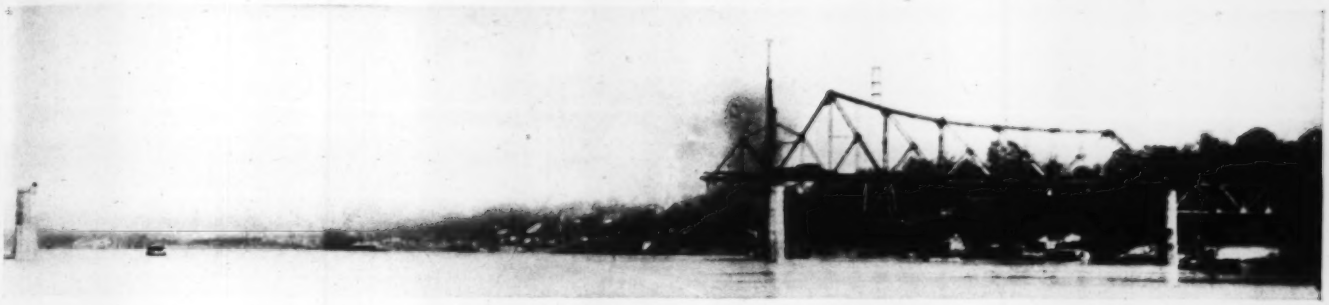
Above: Chute-a-Caron dam, Saguenay River, Quebec

Above: Fort Lee suspension bridge over Hudson River, New York. Center span 3,500 ft.

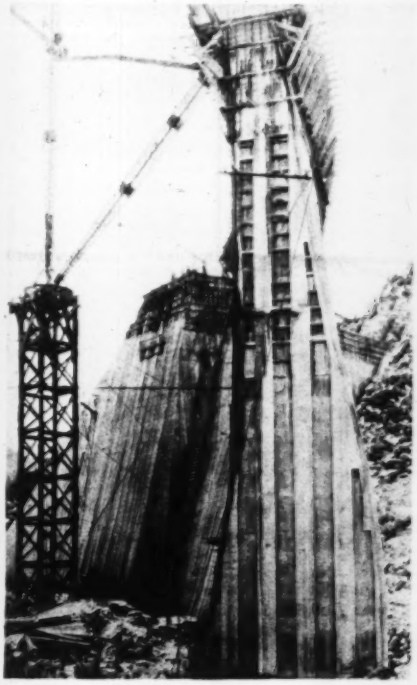


Above: 85-ft. diameter steel dome on Adler Planetarium, Chicago

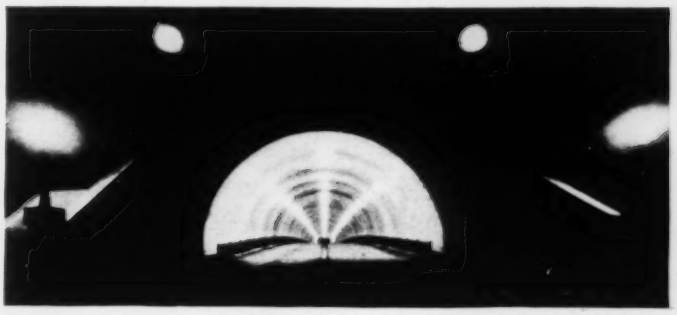
Right: Boeing System airport, Burbank, Calif., with 300x3,500-ft. runways



Top (both pages): Combination railroad and highway bridge over Mississippi River at Vicksburg

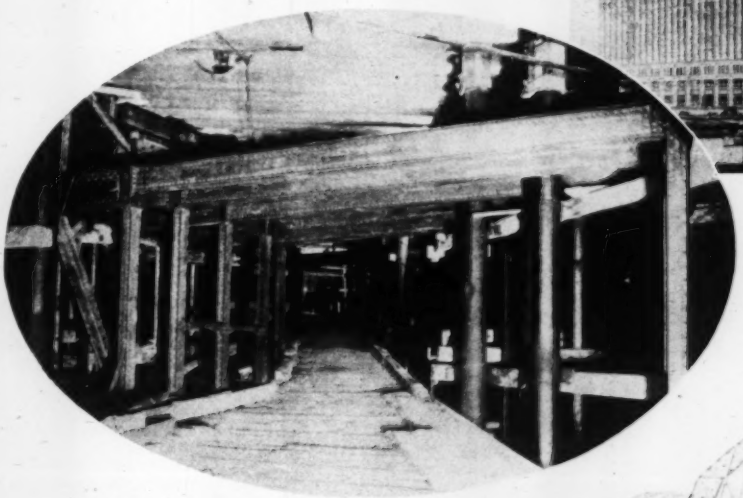


Above: Stewart Mountain dam, Salt River irrigation project, Arizona. Section shown is 118 ft. high, maximum height 212 ft.

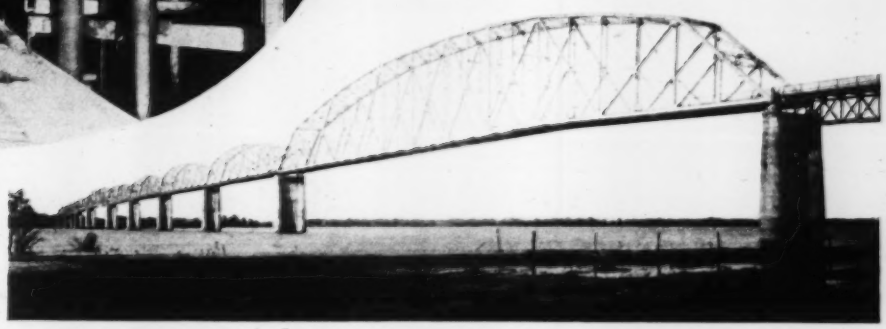


Above: Beaucatcher vehicular tunnel, Asheville, N. C.

Below: Merchandise Mart Building, Chicago. Largest industrial building in the world, 724x580 ft., 18-25 stories. Basement is freight terminal of C. & N. W. Ry.



Left: North end of new Nassau St. subway, New York. Steel for permanent subway structure being placed among cylindrical piles carrying overhead elevated railroad and street with surface car tracks

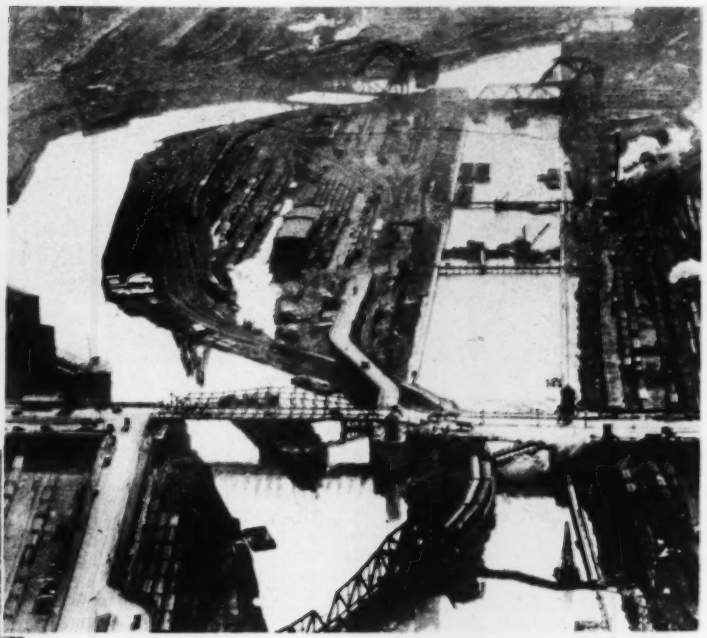


New highway bridge over Ohio River, Paducah, Ky.

1,027-ft. cantilever main span, Montreal-South Shore highway bridge over St. Lawrence River

Above: Heavy rock cut on D. & R. G. W. Railroad relocation near Florence, Col.

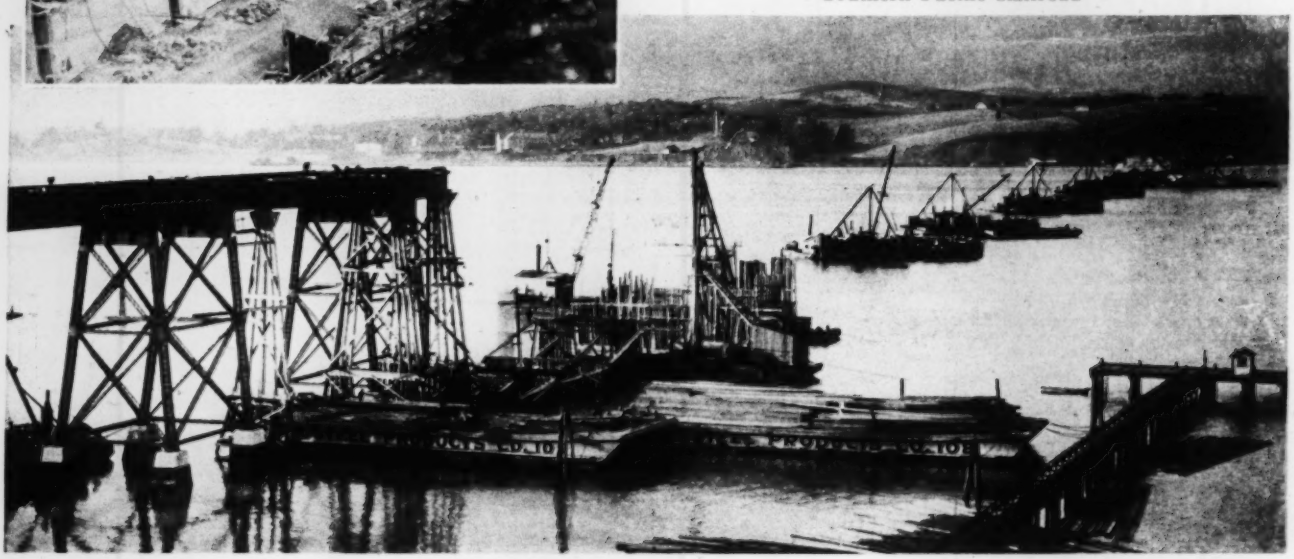
Below: Wyman rolled-fill dam, Bingham, Me. Concrete core wall on pneumatic caissons



©Chicago Aerial Survey Co.

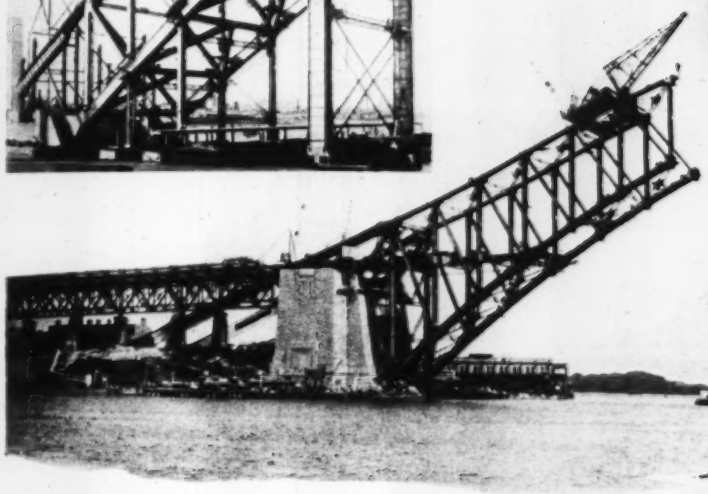
Above: Chicago River straightening project

Below: Pier construction for 6,000-ft. double-track bridge across Suisan Bay, Calif., Southern Pacific Railroad



Above: Unwatered site of Owyhee dam, Washington. Downstream cofferdam in background

Below: Track work on Cleveland Union Terminal



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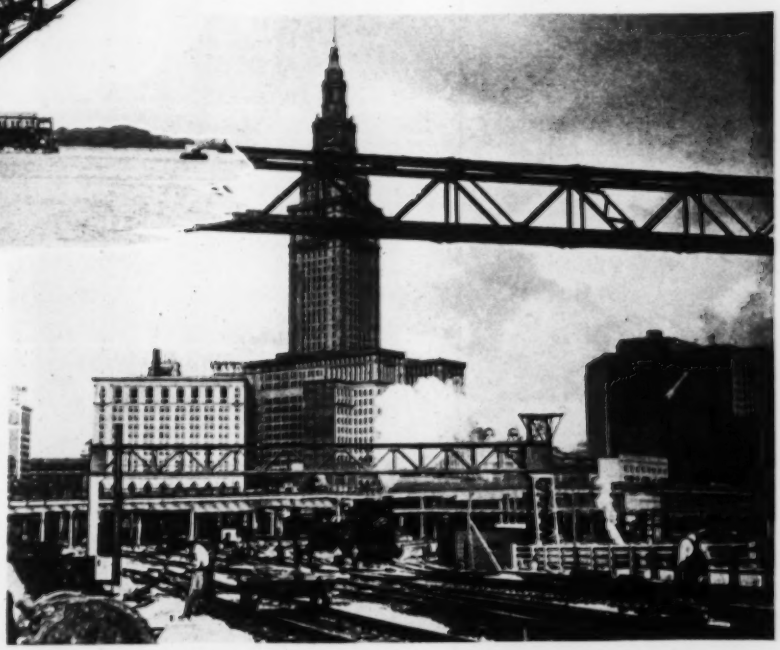
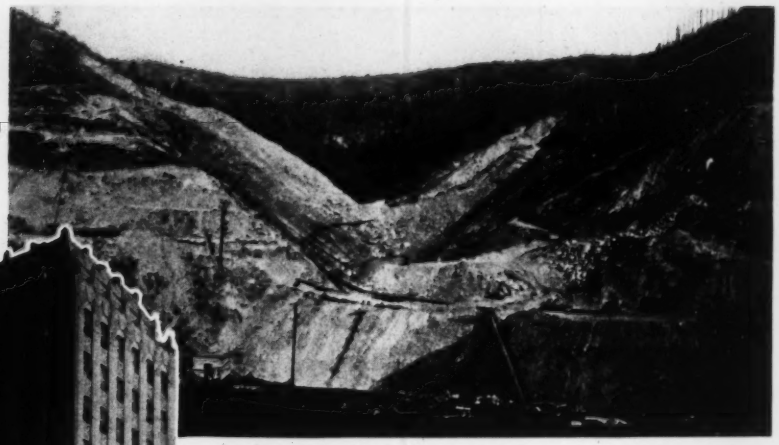


Above: Two of the world's longest arch bridges. 1,675-ft. Kill van Kull bridge, New York *(top)* and 1,650-ft. Sydney Harbor Bridge, Sydney, Australia

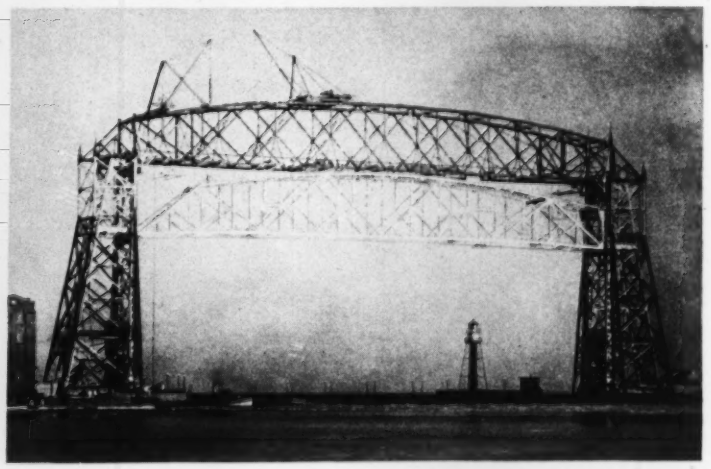
Below: Two-bridge highway project over Cape Fear Rivers, Wilmington, N. C.



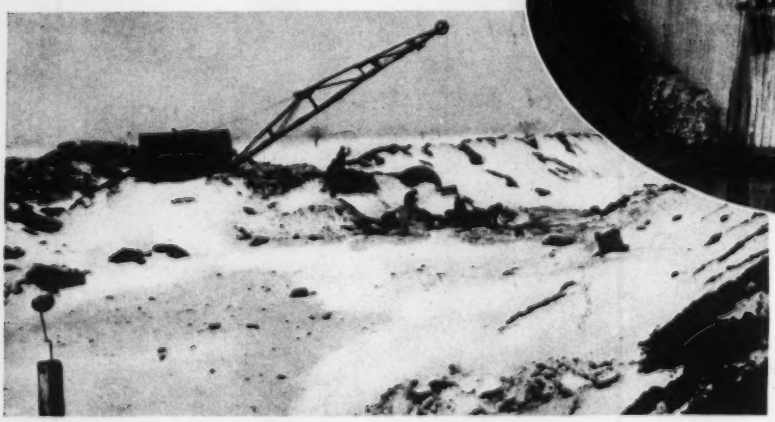
Left: Cobble Mountain hydraulic-fill dam, 245 ft. high, for Springfield, Mass., water supply

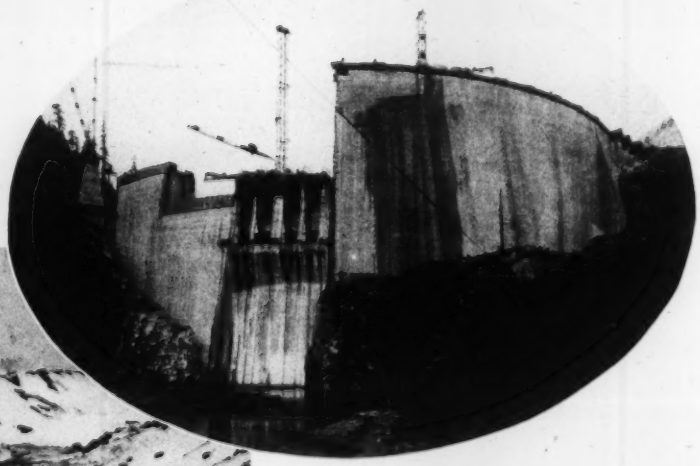
Below: Vertical lift bridge over Duluth Ship Canal replaces old ferry bridge. Light-colored steel is new structure

Above: Reinforced-concrete Wilshire Professional Building, Los Angeles



Below: Rock excavation on Beauharnois hydro-electric project, Quebec





Above: 400-ft. Diablo dam on Skagit River, Wash., for Seattle water supply

Mississippi Flood Control

Origin of the Plan of Flood Control, the Major Elements of This Plan and the Principles Conceived to Govern Its Development and Prosecution, With Suggestion of Prospective Changes

Harris & Ewing Photo

LYTLE BROWN, major-general, U. S. Army, an 1898 West Pointer, was chosen to build the Mississippi flood-control works because of his distinguished record as administrator. Was chief of the war plans division of the General Staff during the war.

BY LYTLE BROWN
Major-General, Chief of Engineers, U. S. Army, Washington, D. C.

THE flood-control project for the lower Mississippi Valley was adopted by the act of May 15, 1928. The project is outlined in general terms in the report of the Chief of Engineers printed in House Document 90, 70th Congress, 1st Session. The customary procedure sanctioned by long practice is for such projects to be adopted in general terms, leaving details to the Chief of Engineers. This project as adopted by law is general in its scope, with the responsibility for the execution and for the details of design and location of the engineering works and structures placed upon the Chief of Engineers under the supervision of the Secretary of War.

How the Project Was Created

The flood-control project was based on data which had been collected by the Mississippi River Commission over a period of 48 years. These data are so voluminous that the chief problem in formulating a project lies in digesting all the available information, using the essential facts that have been determined and deciding upon a simple, common-sense plan. However, the organization of the Corps of Engineers, U. S. Army, has so many men familiar with the Mississippi and its hydraulics that the formulation of a project based on general assumptions is not a matter of great difficulty.

Since the flood-control plan was adopted by Congress, *Engineering News-Record* has published in detail the plans for all the new and special features of the project—viz., the Birds Point-New Madrid floodway, the Bonnet Carré spillway and the floodways in the Boeuf and Atchafalaya basins. The Birds Point-New Madrid floodway and the Bonnet Carré spillway have been started and are being prosecuted as rapidly as possible. The plan of the Birds Point-New Madrid floodway is being carried out practically as it was conceived before the project plan was presented to Congress. The Bonnet Carré spillway is the same in general dimensions as the plan of the Spillway Board, which was the plan of the adopted project.

The location in detail of the spillway was changed somewhat in order to place it in the most stable location available. Also the spillway structure is to be a needle dam, whereas the Spillway Board contemplated a stop-log dam. Both are simple to operate and avoid complicated operating machinery. Both can be operated much faster than the river rises or falls and are susceptible of operation a great deal faster than is required by the conditions of the project—viz., to keep the Carrollton gage at 20. The needle dam distributes the pressure uniformly and thereby tends to avoid unequal settlement on alluvial foundations. It also is operated from the top and involves no operating machinery or devices under water. Although a condition which would require fast opening is considered impossible, the needle dam could be tripped, if necessary, and opened almost instantaneously. It is cheaper than any other type of movable dam or dam with gates.

It has been suggested that a break in the side levees of the Bonnet Carré floodway might cause a situation in which it would be desired to close the spillway more rapidly than the river falls. This is impossible under the requirements of the project, which require the Carrollton gage to be kept at 20. If the Carrollton gage is at 20, there will arise no demand to stop water flowing out of the spillway and force it past New Orleans at a higher stage than 20. In 1927 New Orleans blew up a main river levee to keep the Carrollton gage down to 20. In addition, the side levees of the Bonnet Carré floodway are being built much stronger than other levees in the Mississippi Valley.

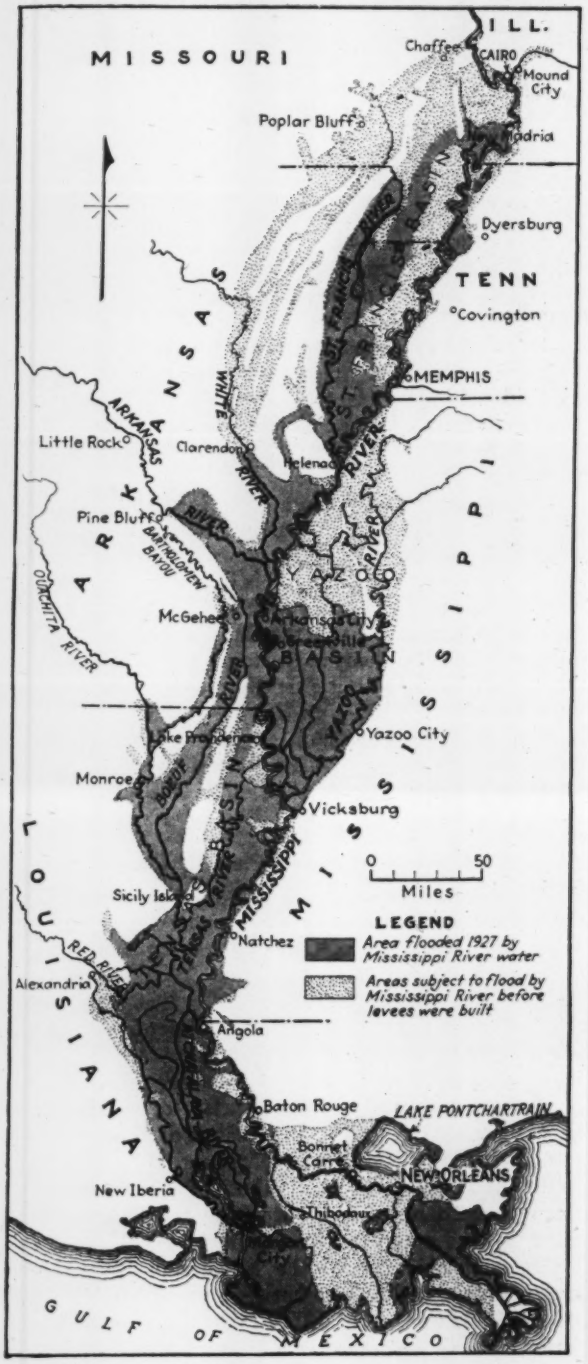
Criticism of Bonnet Carré Spillway

Criticism has been directed in the public prints against the details and location of the Bonnet Carré spillway. None of these criticisms covers points that have not been fully considered by those responsible for the location and design, who are the only authorities that have before them all of the data affecting the building of the proposed work. The main criticism is that the wide, shallow floodway is inferior hydraulically to a narrow, deep one and is vastly more costly. This criticism at first seems to have much weight, tending to a change of plan. On close examination there are seen difficulties that are inherent in the site and they are chiefly those of security. Further, this is a question that does not permit of half-baked argument and the delay occasioned thereby.

The alluvial valley of the Mississippi River (below Cape Girardeau, Mo.) comprises some 20,000,000 acres of land. Of this, about 12,000,000 acres are now usable. Prior to 1850, when the United States turned over to the states certain swamplands, the Mississippi Valley was

settled and cultivated in sections which protected themselves from floodwaters to a certain degree. Since that time reclamation has increased, populations have grown and large sections have become prosperous agricultural areas dotted with towns and villages. Railroads and roads have been built in this most fertile valley and the national government has undertaken the expense of flood protection to a degree far beyond anything contemplated in the early days. As the lands have been progressively protected, their population and use have increased by leaps and bounds. It is to be expected that similar development on a greater scale will follow additional flood protection.

The great question is, How can flood protection be best secured? Can complete protection be secured for the entire 20,000,000 acres of the valley, or must man be content with protecting only a part of this territory? If it is not possible to protect all this land completely, is it better to protect completely a portion of the areas involved and leave certain areas surely subject to periodic overflows? Or is it better to leave the entire area subject to possible overflows of uncertain depths and uncertain frequency rather than to leave a part of the lands to carry the water with greater depths and more certain frequency? In this connection it must be realized that the lands completely protected will lose thereafter the periodic refertilization which nature provides with overflows. Also it must be further realized that they will be free from top erosion and deposits of sand. The majority of the people undoubtedly prefer the complete protection.



MISSISSIPPI VALLEY SUBJECT TO OVERFLOW

The general conclusion is that complete flood protection is not practicable even at the present time for the entire alluvial valley and that certain portions must be left to provide discharge space for floodwaters. However, there are those who claim that complete protection for all the lands is feasible by stopping the water near its source and holding it in reservoirs on lands that are outside the alluvial valley proper. Again, there are advocates of protection partly by reservoirs and partly by floodways in the valley. The question as to which lands will be subjected to overflow appears to be whose ox is gored. In any event the United States is asked to pay for the lands subjected or left subject to overflow. These lands were practically given away once and now it is asked that they be bought back. No objection, perhaps, but the price must be according to present worth.

Flood Magnitude and Safety Margins

There seems to be a fairly general agreement that it is not expedient to confine all the probable or possible excess floodwaters of the Mississippi to the main channel, or, rather, between the controlling levees of the main channel. The river needs more room, and if it is not given the space it requires it will take it. The problem is to determine how much it requires and to give that and no more. This must be done with factors of safety that are reasonable in view of the uncertainties involved as well as the resulting cost of a possible underestimation of the room required.

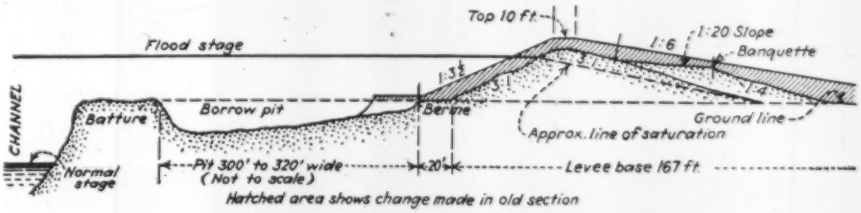
It is only prudent that we should protect against a flood about 25 per cent greater than that of 1927. Such a flood will, of course, be very rare on the average, yet is as probable today as a century hence. Having settled upon so great and so rare a flood, it must be kept in mind that the flood assumed embodies the necessary factors of safety and these do not have to be added again to the detailed engineering structures all down the line. For example, a levee with a 1-ft. freeboard on this imaginary superflood would have a freeboard of 3 or 4 ft. for a flood equal to that of 1927, and no greater freeboard as a factor of safety is warranted. (A flood equal to that of 1927 will be rare on the average; only once in history has such a flood occurred.)

How Flood Control Is Accomplished

Flood-control works proper include levees and revetments. There are to be levee lines along the main river and also in the side basins to protect the best lands from excess floodwaters that may pass toward the Gulf through the side basins outside of the main channel. Revetments are used to prevent bank caving and destruction of levee lines. They also stabilize the banks and reduce the earth that is being constantly picked up and

carried by the river. They are an aid to the navigable channel as well as a protection for levee lines. Contraction works are used in the main channel to decrease the cross-section of low water flow and thereby increase the navigable depth. They serve to reduce maintenance dredging. These have no bearing on flood control; so we have levees and revetments for flood control and contraction works and dredging for navigation, with revetments serving both.

Prior to the 1927 flood the scheme for flood control of the Mississippi involved levees only on the main channel. It was thought that all probable floodwaters could be held within the controlling levee lines along the main river. In addition it was believed by some that the restraining of the floodwaters to the main channel caused the floodwaters to enlarge that channel progressively and thereby



NEW LEVEE SECTION SUPERIMPOSED ON PRESENT SECTION

the floodwaters would gradually make a channel sufficient for any and all floods. This view was not concurred in by all engineers. Even some who for economic and practical reasons favored "levees only" on the main river did not think that they had any material effect in enlarging the river channel. The opposing opinion is that the channel of the river is made by the year-round flow and that large floods occurring rarely do not materially affect the channel capacity. Even if floodwaters would do what is claimed by advocates of "levees only," the scheme is not practicable, since protection is desired now, and we must provide the necessary discharge areas many years before such a scheme could work itself out. The necessary discharge areas having been provided, there is no great advantage to be gained even if the floodwaters would enlarge the channel capacity.

Elevation of River Bed Unchanged

In the 50 years during which data have been collected on the Mississippi River, although the confinement of the river between levees has caused large increases in flood heights, it has not caused any cumulative changes in the elevation of the riverbed itself. The bed and the natural banks of the river are continually undergoing the local changes found in any alluvial stream subject to a widely varying discharge, but the gross effect of these changes on the discharge capacity of any considerable section of the river proper, since the construction of levees was started, is so small as to be less than the limits of accuracy of measurement. Neither the levees nor the crevasses that have occurred in them have had any measurable effect on the capacity of the channel of the river itself to carry off floodwaters.

After the flood of 1927 had demonstrated that it was not practicable to restrain within the main channel of the Mississippi River below the Arkansas River all the probable or possible floodwaters, it was necessary to find ways for the excess floodwaters to flow to the Gulf through the side basins. The most practicable paths are located on the west side of the Mississippi where the lands are low and wide all the way. There are several alternate routes over parts of the distance, but it may be said that generally the excess floodwater must pass through the Tensas basin, through the Red River backwater area and through the Atchafalaya basin. If levees are not to be raised to a marked degree on the main river, approximately a million second-feet must find its way to the Gulf outside the main channel.

Levees and Revetments

To reduce the probability of accidental crevasses it is necessary that the main river levees be strengthened and raised slightly. The section generally used previously had an 8-ft. crown, a slope of 1 on 3 on the river side and a slope of about 1 on 5 on the land side. The new section being generally used has a crown of 10 ft., a river-side slope of 1 on 3½ and a land-side slope of about 1 on 6. Where the soil is sandy the levee must have a decidedly greater section. The section authorized is ample to include the line of saturation and is to vary with the materials and foundations in different localities. The raising contemplated is usually limited to 3 ft.

Levee enlargement is mostly by contract. The increased amount of work and the size of the contracts is an incentive for new and larger contractors to enter this field of activity. There is also an incentive to encourage development in the methods of handling earth under the conditions of levee building. Average prices in the three districts on the lower Mississippi range from 21c. to 27c. a yard. The methods used vary in different localities. It is hoped that some cheap method of building levees by dredging will be developed.

Revetments are constructed by government plant and hired labor. The plant necessary is so expensive and the work so uncertain and varying that no contractor has found it expedient to purchase the necessary equipment for this kind of work. Both brush and concrete revetments are used and the schemes in use accomplish the result desired—viz., the prevention of caving banks. The cost is so large that it is generally cheaper to set back the levees than to protect caving banks. However, at places the prevention of caving is essential. The development of economical and durable bank protection is the greatest need at present of navigation interests on the Mississippi River.

present of navigation interests on the Mississippi.

The revetments now being used are the result of many years' experience and experimentation to determine the most economical method of preventing banks from caving. For a long time only brush revetments were used. These consist of fascines bound by wire cable with the separate fascines also tied together with cable. When fascine material began to grow scarce and expensive, concrete revetments were undertaken. By experimenting, satisfactory flexible concrete revetments have been developed.

At present there are two general types in use. Both consist of concrete slabs tied together with wire. In one type the slabs are larger (5x11 ft.) and overlap in shingle

fashion. In the other type smaller concrete slabs (1x4 ft.) are fastened together by wire with butt joints. Recently old mattresses have been examined by divers and it has been found that the types used last many years. The use of copper wire would prolong the life of revetments, but by reason of the expense of such wire it has not been considered expedient to use it.

The adopted project provides for the use of contraction works south of Cairo, Ill., to improve the navigable channel and reduce the amount of maintenance dredging necessary. The types of these works in use are those which have been previously tested out in the river north of Cairo. Generally they are permeable dikes consisting of two or more rows of clumps of piles braced together. The piles are driven through a mat laid on the bed of the river, and the bank at the end of the dike is protected with a mat below water and paving above the low water line. The dike causes deposit and building up from the bottom. The current between the ends of dikes in midstream or between the midstream end of one dike and a protected opposite bank scours out a channel deeper than the natural depth.

Floodway Flowage and Control

Much publicity has been given to the question of floodways, with widely varying opinions as to the widths that are expedient. The economics involved are under discussion. The author of the adopted project considered that wide, uncleared floodways were the only practical solution of the problem; that they were far and away the most economical solution whether or not the lands in question should be paid for. Without entering into this phase of the flood-control question it can be stated that a recent pamphlet issued by the Board of State Engineers of Louisiana gives the total full value of the floodways south of the Arkansas River at approximately $172,000,000, including lands, industries, railroads, highways and drainage canals. Of this, about $51,000,000 is the value of timber lands, leaving about $121,000,000 as the full value of everything else. What the United States government might pay for flowage over this is a question which no one can answer with accuracy.

The question of controlled spillways at the heads of floodways is also a subject of conflicting opinion. One of these would cost about $17,500,000. Whether such a spillway would be actually controlled with respect to water conditions or by injunctions or by illegal acts is a matter of opinion. If the matter of paying for land or flowage below the sites of proposed spillways is settled, the difference of opinion as to the expediency and economic justification for such structures may disappear.

The organization for doing the flood-control work of vast size is quite satisfactory. The president of the Mississippi River Commission, located at Vicksburg, Miss., the approximate geographical center of the job, is in charge of the work. Under him are three district engineers, at Memphis, Vicksburg and New Orleans, respectively. Each has about one-third of the work, and the areas within these districts are further subdivided. Under the Chief of Engineers the work is carried out expeditiously and efficiently. The money appropriated annually is used where the need for it is most apparent.

Every effort is made to do as much of the work by contract as is possible. No work is done by government hired labor forces except when it is impossible to get the work done as economically by contract. Contracts can be let at 25 per cent more than the cost if done by day labor, and they are frequently made at higher figures than the government estimates. No steps other than those being taken are possible to give more encouragement to contractors to enter this field of work and to develop machinery and methods of the greatest efficiency. The desire of all concerned is to encourage the contractors of the country to enter this field.

Necessity for Action

Since the project was adopted by Congress and made a matter of law very little effort has been made by those responsible for the work toward inquiry as to how the general plans might be modified. This may be deemed by some as a fault. It is, on the contrary, a cardinal virtue. In the words of one of the greatest of our Presidents we say, "Take all the time for consideration that the situation permits, but when the time for action arrives stop thinking, cast all ruminations and doubt-creating thoughts aside, and proceed to execution with all of the vigor of mind and body that you possess." Those who expect new schemes to be evolved and new ideas to be introduced or adopted, to fundamentally change matter while execution is in progress, will do well to give thought to the necessity for action.

But there is a phase of the adopted plan which cannot be ignored by any one without incurring the charge of obstinacy as opposed to firmness. And that idea is the possible cost to the United States in the way of damage claims resulting from an interpretation of the law and the evaluation of land, railways and roads to be flooded. It is this aspect that has caused us to pause and look around to see if by a change of plan this matter may be clarified or the danger of possible vast expense avoided. This pause has been of very recent date and action resulting from it cannot now be forecast.

The present dissatisfaction in some quarters arises from a fear of injury without due compensation rather than from any inadequacy or fault of the legally adopted plan. In the minds of those who are responsible for the execution of the work its economic phase must enter powerfully. There are several projects of vast economic value to our country that should be accomplished. Unless each is done with the utmost economy, the others will suffer and be delayed accordingly. No man, no company, no country can ignore the fundamental law of economy—every dollar spent must bring in a sensible return in accord with the value of money.

I believe that if the damages resulting from the flood-control works in the Mississippi Valley are estimated sensibly, accurately and justly on the present economic status without regard to vague, exaggerated or speculative values, the present plans or any reasonable modification thereof can be executed to the economic general advantage of the United States. If unit values of land, railways and roads are raised to meet sentiment or exaggerated ideas of value, then the economic status of the project is at once brought into the shadow of doubt, into which no official responsible for the expenditure of public funds should venture.

There is a deal of discussion about protecting land, and it is of no small importance, but there is not enough discussion about protecting the localities where the nerve centers of the country lie, the centers of business, terminals and transportation, of which, in the region affected, the great port of New Orleans is the chief. These, like the command posts in battle, are of decisive value.

Any changes in plan will be directed toward securing adequate results with certainty, at the minimum of cost with due regard to time of execution, and will depend on

a possible combination of levees, floodways and reservoirs. Of these three the use of reservoirs is most in doubt and may come in not at all or slowly as a supplementary measure only. But as aforesaid, no forecast of the changes to be made can be definitely set forth at this time.

No suggestion from responsible authority has yet been made that proposes to eliminate either of the floodways known as Atchafalaya and Bonnet Carré. These are necessary for the protection of New Orleans. Very strong arguments have been made toward the elimination of the Boeuf floodway. Those making this argument, notably the Board of State Engineers of Louisiana, have substituted therefor the system of reservoirs on the Arkansas and White rivers as set forth in studies of the reservoir board of the office of the Chief of Engineers. That system of reservoirs includes as its principal factor a huge reservoir across the main stem of the Arkansas River just above the city of Little Rock. The objections to a high dam in this locality are too obvious to fail of notice on casual examination. Its elimination, if practicable, is to be sought, since obvious objections would be quite as strong in many respects as any of those brought forward against the floodway in the Boeuf basin.

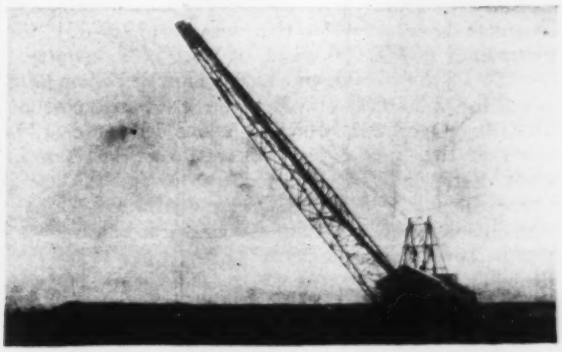
It should be evident to all who have studied the question of reservoirs that any of them built for the purpose of flood control in the lower Mississippi must be operated and regulated for that purpose primarily. Those who advocate them for local benefits as primary reasons are likely to be disappointed in their results as regards either power or local flood protection if they are operated for the benefit of the situation on the Mississippi River. There can be no half measures in the operation of these reservoirs. They are for one purpose or the other and must be operated accordingly.

While the work is being pushed with the utmost vigor, esearch to develop new processes is also being carried on. A hydraulic laboratory is being established at Vicksburg, Miss., under the direct supervision of the president of the Mississippi River Commission. This laboratory will test out with models all reasonable ideas advanced, and the research personnel will also make measurements and carry on full-scale tests on the river itself wherever and whenever an opportunity becomes available for such tests.

The organization provided for the work is fully satisfactory and embraces the two main desiderata—a single and individually occupied line of authority for execution, and a commission (board) for advice and counsel. The personnel is as good as America affords, being that which has had the most thorough knowledge through actual experience in the conditions to be met. All officers of the Corps of Engineers, U. S. Army, are prepared to a certain extent to serve on the Mississippi River, by a thorough course of study on the characteristics of the stream and the methods of work developed for its improvement. Specially selected ones serve there. The closest cooperative and consulting relations are encouraged and maintained between the government's representatives, from the Chief of Engineers to include those in the field, with the men who live in the valley, whose interests lie there and who have a lifelong experience with the river.

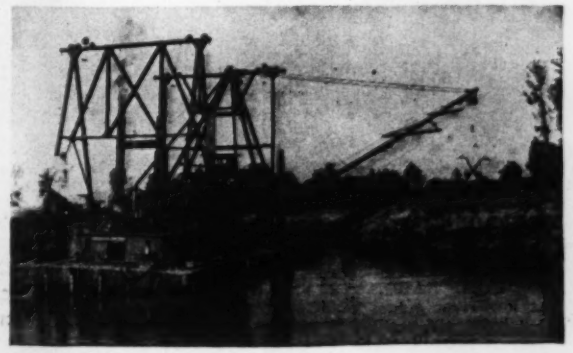
REPRESENTATIVE LEVEE-BUILDING AND ENLARGEMENT EQUIPMENT

Above—The view shows clearly the section of new fill: the slope of the old levee plowed to give bond, and the notably exact slope of fill produced by the cableway bucket.



Above—This is typical as to appearance and size of the largest new dragline equipment for the superflood levee section. These draglines pick up material and place it 320 ft. away.

Below—The dredge, with a 240-ft. boom and 6-yd. bucket, is digging in from the river to working position in the borrowpit. The pond level is well above river level.



Below—Almost ideal pit conditions; friable loam after a long dry spell. Both grader and wagon are tractor hauled. The grader has just begun to "load."

Levee-Building Operations

A Summary of Present Operations in Which the Evolution of Methods and Machines Is Set Forth—A Large-Contract Plan Has Been Inaugurated and Will Continue—Contracts for 1930-31 Are to Be Awarded Early in the Year

Introduction

By T. H. JACKSON
Brigadier-General, Corps of Engineers,
President, Mississippi River Commission, Vicksburg, Miss.

IN GENERAL, construction progress on Mississippi flood-protection work since the initiation of the present superflood project has been very satisfactory. All available funds are obligated. The cost of the work to date has shown that the estimates both of volumes and of unit costs are sound and that there should be no difficulty in performing the work contemplated by the project within the estimate.

It is expected that bids for the work to be done under the appropriations for the fiscal year 1931 will be opened in March and April instead of May to August as for the fiscal year 1930. This should permit the awarding of all contracts except those for emergency work within a month after the funds become available, about May 1, 1930.

Contracts have been let this season (1929-30) for approximately 68,000,000 cu.yd. of levee at an estimated field cost of $15,840,000, and hired-labor work has been initiated for 7,500,000 cu.yd. at an estimated cost of $1,640,000. Overhead, which is about 15 per cent, is included in the hired-labor estimated cost but not in contract cost.

The trend has been toward larger contracts. During the season continuing contracts were awarded as follows: Memphis District, eight items aggregating 11,650,000 cu.yd. at an average cost of 25.2c.; Vicksburg District, seven items aggregating 8,890,000 cu.yd. at an average cost of 29.25c., and New Orleans River District, six items aggregating 14,200,000 cu.yd. at an average cost of 20.8c.

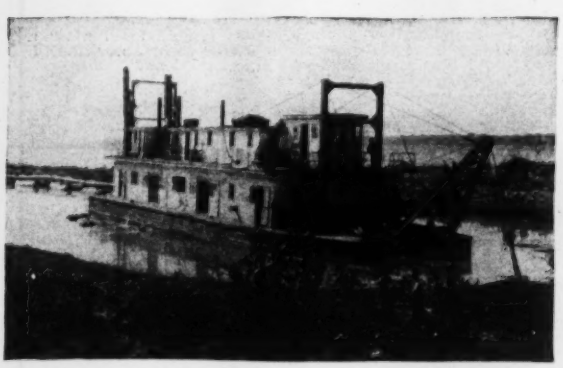
THOMAS H. JACKSON, brigadier-general, U. S. Army, West Point 1899, gained experience in flood-control work in the Sacramento Valley, was one of the board of three which reviewed the Mississippi project in 1928. President, Mississippi River Commission.

In the New Orleans River District, excluding the hydraulic fill for the Bonnet Carré side levees, the prices have ranged from 11c. a cubic yard for the smaller Mississippi River and south bank of Red River levees to 27c. for the largest main river levees. The hydraulic-fill base for the Bonnet Carré side levees is costing 21.21c. by contract.

There has been a downward trend of prices in the Vicksburg District, due both to the use of wet methods and to the larger volumes. Wet methods permit operation all the year around, and large quantities and longer-term contracts reduce mobilization and demobilization expenses and intermediate lay-up costs, besides justifying contractors in acquiring more efficient equipment.

In the Memphis District the general trend of prices on enlargement is upward because of longer haul and exhaustion of old borrowpits. On new levees it is downward, due to large quantities.

In the New Orleans River District—again excepting



HYDRAULIC DREDGE BUILDING LEVEE BASE
This represents typical dredge practice. The machine has a 12-in. pump, cutter head suction and diesel power. It is operating in a pit parallel and close to the river.

PUMP BARGE FOR FILLING DREDGE POND
At low river stages pumping from the river is at times necessary in order to provide water for the dredge pond in the borrowpit to float the machine.

the Bonnet Carré floodway—there has been little change in general methods. Dragline excavators continue to be the most generally used levee equipment. These include seven new machines of three makes having 150-ft. booms and 5-yd. buckets. One contractor expects to place a long-boom California-type dredge on one job, and another is about to commence work with a specially constructed belt-conveyor type of floating machine. The machine will dig its flotation but will maintain dikes so that only dry material will be placed in the levee.

The side levees of the Bonnet Carré floodway are specially designed on account of the swamp conditions over most of the area. Approximately 1,000,000 cu.yd. located relatively near the river is being placed by dry-fill methods. The remaining 7,000,000 cu.yd. is being placed wet by floating equipment; of this, 5,500,000 cu.yd. will be hydraulic-fill base and the remainder will be retaining dikes and superimposed fill.

The Vicksburg District has witnessed increasing use of hydraulic fill. In 1929 contracts were let for seven hydraulic-fill operations out of twenty main items.

The Memphis District reports that wet-fill methods will not be as generally applicable in levee construction as thought at first—though in certain situations they will be able to compete favorably with dry-fill methods

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A Survey of
Construction Conditions, Methods and Plant

By C. S. Hill

Associate Editor, Engineering News-Record

WITH work well begun on the enlarged levee sections, it is plain that Mississippi flood protection under the new plans can be accomplished with any degree of dispatch that the money annually made available will allow. A basic engineering organization now exists which can readily be extended, the number of contractors is ample for all the work that is offered, and manufacturers have been active in developing new machines and particularly in improving old machines.

An inspection of levee-building operations from Cairo to New Orleans discloses these definite facts: (1) Levee building has become more completely mechanized; (2) the introduction of new machines is active and courageous; (3) old machines have been improved mechanically and increased in size and power; and (4) study and appraisal of processes and machines are necessary (*a*) to co-ordinate plant and procedure in individual methods of work and (*b*) to co-ordinate methods of work with construction conditions.

Unusual Conditions Confront Contractors

Conditions of two kinds have to be considered in contracting for levee construction: (1) those created by the specifications and by the established contracting procedure, and (2) those due to physical characteristics,

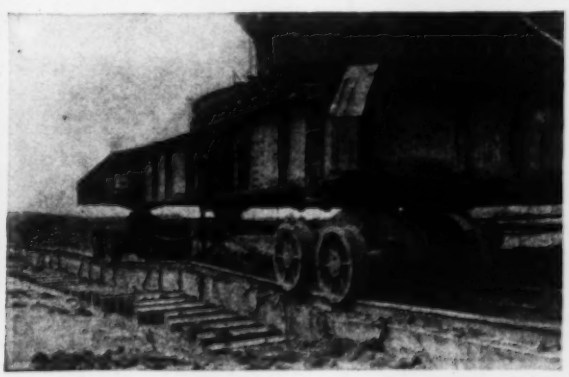
CHARLES S. HILL, Vermonter, an editor all his active life, has carried on intimate study of large construction for 35 years, beginning with the Chicago Drainage Canal. Has spent many months in observing the current flood-control operations on the Mississippi.

location, topography, soil and drainage. Both are unlike those encountered in general earthmoving practice. Disregard of this fact, more often than any other error, has been the cause of unsatisfactory experience by contractors new in levee construction.

Government Competition—The government is a potential competitor for every levee contract. Its engineers' estimates are virtually bid prices for which they stand ready to construct the levee by force account. If the low bid by a contractor plus a varying percentage added for engineering supervision is less than 25 per cent greater than the bid by the government engineers, they are empowered to award the contract, but are not required to do so. Generally they do award the contract, but not invariably at the price bid by the contractor. They may "in the best interest of the government" ask the low bidder to cut his bid price as the condition of receiving the contract, and certain contracts have been executed on this basis.

Lump Unit-Price Requirements—The specifications require the price bid to be a lump unit (cubic yard) price for net section; this price includes clearing, grubbing and preparation of foundation, drainage, dressing and sodding. It also includes the additional yardage

DRAGLINE LOADING INDUSTRIAL RAILWAY TRAIN
Train and dragline operate on the surface. The pit was wooded and cleared; note how the dragline has worked around and piled up the stumps and roots.



TRUCK TRACTION FOR LARGE DRAGLINE MACHINE
This formerly was the standard dragline mounting, succeeding the skid and roller mount, and it still is being used on some of the largest new machines.

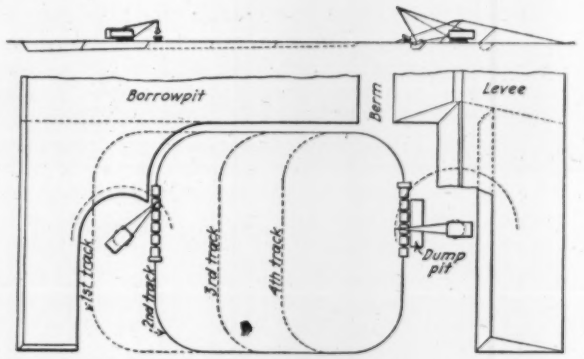
for a gross section large enough so that shrinkage will not reduce the levee to less than net section. The yardage specified to be added for shrinkage varies from nothing for hydraulic fill to 15 per cent of the net fill for scraper work, tractor and wagon work, or animal and wagon work, and 25 per cent for other methods, including work by draglines, tower machines and other machine scrapers.

These shrinkage allowances are constant regardless of material. The yardage for shrinkage also has to be so placed that the final shrinkage shall be true to the slopes of and not less in dimensions than the specified net section. In brief, the contractor has to build a gross section up to 25 per cent greater in volume than the net section (pay yardage), and has to shape and dress and sod this section.

Of the items included in the cubic-yard price, drainage demands special attention. The amount required varies with river stage, topography, soil and batture conditions. It varies, therefore, on almost every operation, but always the groundwater level and seepage flow are not far down and in a rainy season surface water piles up rapidly in the pits. This water must be removed in dry-fill levee work because the contractor cannot work effectively in wet pits and because the engineers will not allow any considerable amount of wet material to go into the fill.

Borrowpit Restrictions—Borrowpits are normally restricted to the river side of the levee, are in general kept at least 40 ft. away from the fill and are very shallow. Deeper borrow is permitted in the New Orleans River District (1 on 2 to 3 ft. deep and then 1 on 10), but for the major length of the river it is 1 on 2 to 3 ft. deep and then 1 on 50. Where the work is enlargement of old levee and the borrowpits were rather completely worked out for the original fill, the situation is intensified, since the old pits may not be deepened and can only be widened. The condition is somewhat bettered in turnover levee work where the old levee can be borrowed to help make up the new fill.

Payment Practices—Payment for work and completion of the contracts are contingent upon available funds, which in the case of a straight contract are always in hand before the contract is entered into. In a continuing contract the available funds at the beginning are only some fraction of the total money commitment. The remaining funds are contingent upon continuing appropriations by Congress. These are virtually always made and in time for the money to be available before the previous appropriation is exhausted.



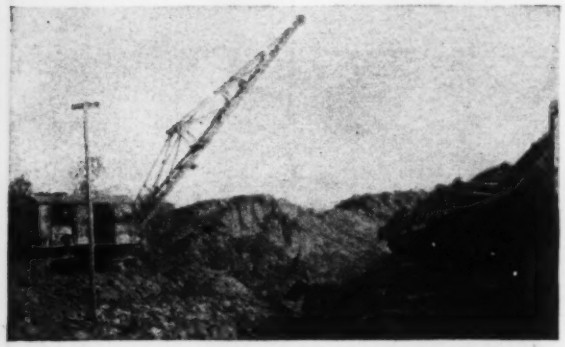
IDEAL TRACK LAYOUT FOR INDUSTRIAL RAILWAY OPERATION

In case exhaustion of funds is apparent before new appropriations are available, 30 days' notice is given the contractor that work may be suspended. However, if the contractor elects he may, so long as funds are available for inspection, continue work on a deferred payment basis until the new appropriation is available; if he suspends work, he receives an extension of time equal to the period of suspension, but is entitled to no damages or other compensation for delay. These conditions indicate a contingency in financing construction which the levee contractor may have to meet.

Partial payments are made on monthly estimates of net yardage in place: up to 67½ per cent of its value for fill not built to full gross section, and up to 90 per cent of its value for fill completed to gross section except as to timber felling, dressing and sodding. Levee completed except as to timber felling and sodding is "accepted" in lengths of 500 ft. or more, to the extent of relieving the contractor from liability for future damage to the work so accepted. Therefore the levee-building processes are generally devised on the postulate of completing the levee as the work goes along.

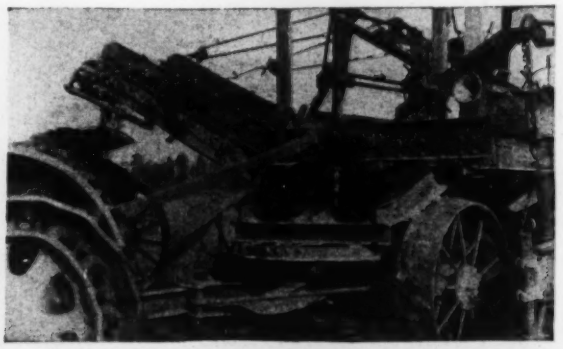
Rigid Supervision—Engineering supervision of contract construction holds closely to the letter of the contract. This comes partly from the traditions of the army engineering service, but is more largely due to the close audit of accounts by the comptroller-general's office at Washington, which countenances scant infraction of contract terms if payment is to be authorized. There is little of the give and take in levee work which is frequent in general earthmoving operations; the result is less flexible relationship of engineer and contractor.

Information to Bidders—The information to bidders



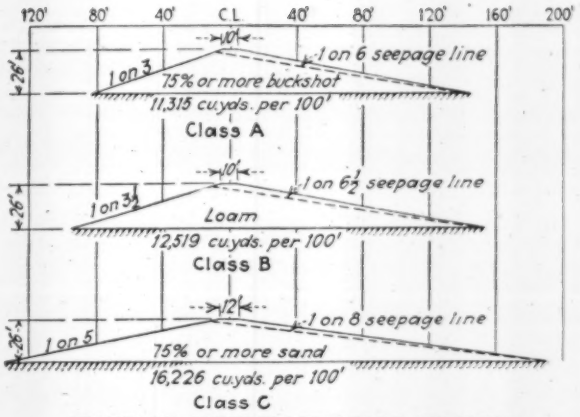
SPOIL PIT FOR INDUSTRIAL RAILWAY TRAIN

Trains from borrow dump into pit in levee the area and parallel to the levee; dragline rehandles dumped material into levee, completing it to full section.



ELEVATING-GRADER POWER TAKE-OFF

Loading belts of the latest elevating graders are operated by a separate engine or by a power take-off from the tractor. The power take-off is shown in this view.



STANDARD SUPERFLOOD LEVEE SECTIONS

is reasonably complete in terms of the contract and specifications. That is, levee location, alignment and cross-section are given, the borrow is indicated and there are ample borings to disclose the character of the material. In a broad way topography and batture conditions are indicated. This information in brief meets a contract which lumps borrow and fill, clearing, grubbing, drainage and foundation preparation into one bid item. It puts the necessity of personal inspection directly onto the bidder.

Soil Characteristics—The delta soils are broadly classified as (1) gumbo clay, commonly known as buckshot, (2) loam, which is a clayey mixture of sand and silt, and (3) sand. The deposits are irregular both in vertical stratification and in horizontal sequence. Any two or all three soils may be found mixed. A pit may disclose alternate layers of any two or all three, or it may be one or the other soil to full depth. Along the levee there may be considerable stretches of one soil, or the type may change every few hundred feet or even every levee station (100 ft.). There is no uniformity of soil for levee construction for any considerable stretch of river.

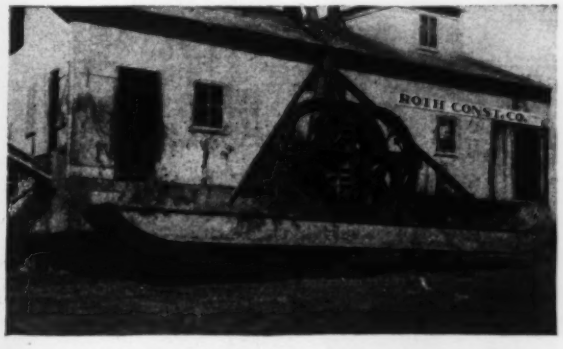
From the earthmover's viewpoint the range of soil types is not only large but the effect on them of water is widely different. Buckshot and loam when dry—with capillary moisture only—will carry heavy loads and can be tracked over by the largest excavators. Both dig and dump clean, the loam well broken up and the buckshot in larger lumps (often full bucket size). With much water both soils become mud—sticky and clinging in the case of the buckshot and sloppy in case of the loam. Neither when wet can be piled in fill of much height without danger of sloughing, nor will it carry load, nor can it be tracked over. Where there is a preponderance of silt in the loam, the mud conditions are intensified. It is the aim, too, to keep silt out of the levee. Sand is a secondary levee material; its characteristics wet and dry are familiar.

Water Conditions—Groundwater level is never far below the surface. There is commonly seepage, which increases with a rising river. A bank-full river brings water into the bayous and draws, reaching inland through the batture. An overbank river inundates the batture. Some of these water conditions always exist and all of them may exist and commonly do in periods of high water. Drainage is therefore a large factor in levee work and its amount and cost have to be carefully appraised in setting a bidding price.

Besides its effect on borrowpit conditions, river level has other important bearings on the work. Largely all movement of large draglines, tower machines and dredges is by river, and the stage of water affects materially the difficulties of loading and landing this equipment and of traveling it inshore to the spot where it is to work. Particularly in hydraulic dredge work, where the machines have to cut in from the river to reach the borrowpit, a high or low stage decreases or increases the task. Also it affects the amount of pumping and the pumping head to supply water to the borrowpit pond in which the dredge works. Not only is river stage an important factor in the work under all conditions but for considerable periods of the year high water virtually precludes any effective work of levee construction.

Batture Topography—Batture topography is of importance chiefly as it affects drainage and overflow, but its tree growth, existing or of some former period, and the measure in which it affords landing and access from the river are matters for consideration. A low batture, one with an inshore sump or lagoon, or one cut with draws or bayous reaching inshore, complicates the drainage and borrowpit problems, whereas one not presenting these conditions simplifies them. Tree growth is significant as determining the amount of borrowpit clearing and the hindrance of stumps to free excavation. On occasion it is not existing growth but the buried stumps of old forests that complicate operations.

Levee Location—Levee location concerns the contractor primarily in respect to accessibility and the measure in which it is favored in soil and water conditions and in batture topography. The servicing of

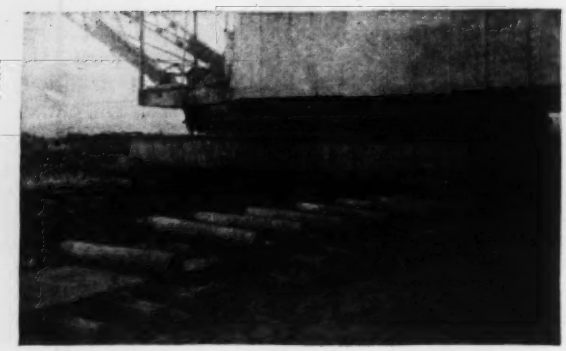


WALKING TRACTION FOR DRAGLINE

This machine travels by taking 7-ft. steps and when operating rests on a large circular base. The walking device permits movement forward or backward as may be required.

DRAGLINE LOADING TRACTOR WAGON TRAIN

This is a reasonably typical train of two 5-yd. crawler wagons hauled by a 60-tractor. The dragline is working from the surface and loading wagons on the pit bottom.



LARGE DRAGLINE ON SKIDS AND ROLLERS
This type of traction is becoming obsolete and is seen only on old machines. Movement is accomplished by taking a bite with the bucket and pulling the machine up to this anchor.

fuel, camp supplies and equipment makes landside roads, accessibility by river and railway and nearness of towns large factors in construction cost. In general, transportation is a vital factor in appraising levee construction problems. The railways on the whole are well back from the river, so that a road haul is required to reach the levee from the railway. Main roads are of secondary types, as gravel or shell, and are also back from the river; the roads leading into the levees and along the levees are earth. Road conditions are therefore a matter of season and weather. A rainy-season road of any of the delta soils is impassable.

Shipment into the work of all materials and plant is either by rail to the station nearest to the work and then by truck haul or tracking over earth roads to the levee, or it is by barge on the river and then by haul or tracking from the landing across the batture to the levee. For very large machines river transportation is virtually a necessity; at many locations it is the best means of shipment of all materials. The transportation system has to be determined for each levee location and is in every instance important enough to deserve close study.

Bearing of Levee Structure on Construction

Levees below Cape Girardeau, Mo., in the present pla.. are plain trapezoids. In this respect they differ from the previous section, which has a two-angle landside slope separated by a banquette. In general, it is an easier section for the contractor to build. This is the only bearing of design in the present consideration.

Structurally the levee is a dumped fill. No compaction is contemplated except that from shrinkage, and this is provided for by the requirement for building a gross section larger than the planned section. It is for this oversize embankment that the contractor has to plan the lift and reach of his equipment; its dimensions are formidable.

A grubbed and plowed foundation and an inspection ditch approximately 5x6 ft. along the center are parts of the levee structure. Where old levee is enlarged, all covered parts are plowed. The inspection ditch is paid for as fill in addition to net section of levee, but foundation preparation is included in price for levee fill.

An Appraisal of Construction Methods

Roundly there are two methods of levee construction: (1) the wet method, which includes hydraulic fill and semi-wet fill by clamshell dredges working in a flooded borrowpit; and (2) the dry method, which includes all processes of making dumped fill from dry borrowpits.

Hydraulic Fill—As employed down the river, hydraulic fill serves several purposes in straight levee construction (distinguished from repair work and pit stabilization). These are (1) hydraulic-fill base and dry-fill top; (2) hydraulic fill to part height but to excess width, which is afterward pulled to the top by dragline to get full height; (3) old levee enlargement by hydraulic fill to one side and excess width which is used to top out the levee by dragline; (4) hydraulic fill of old borrowpits for subsequent re-excavation for levee enlargement.

The year's experience indicates that while hydraulic fill has a definite place in levee construction it is not a levee-building method equally adaptable to all operations; it requires suitable conditions of access, location and water supply and favorable materials, and it is unsuccessful in proportion to the degree in which they are lacking. Hydraulic fill is not a full-section levee-building process below Cairo and it has to be supplemented by dry excavation and embankment methods. There remains a wide field for invention in construction planning and methods. In particular there needs to be study of discharge-pool practice to secure the maximum retention of the solids pumped, quick drainage of fill and the minimum of non-pay retaining dike.

Semi-Wet Fill With Dredges—On the levee construction put under contract in 1929 three clamshell dredges have been installed by one contractor. None has become squared away and got well at its work. All are of the California clamshell type with 240-ft. booms; with this

HYDRAULIC FILL OF BUCKSHOT CLAY
Typical discharge with upturned nozzle pipe. Deposition is largely at discharge. Buckshot breaks up into lumps which are rounded in the discharge pipe.

SILT MUD IN THE BONNET CARRÉ FLOODWAY
After a few days' rain and seepage into the pit the fine river silt becomes a gruel-like slop, into which men sink often to the hips.

boom length the digging reach is about 225 ft. and the swing is about 140 deg. The buckets are capable of holding 6 cu.yd.

These machines have been slow in getting at their work because of the difficulty of digging into the borrow-pit from the river. The low river stage which prevailed during the late summer and fall required a large-scale locking operation, complicated by having to pump from the river to keep the dredge pond filled. The material to be handled is buckshot and loam dug from a flooded pit. The fill therefore will be semi-wet. Results of course are not yet available, but this type of dredge has done exceedingly fast and cheap work on the Sacramento River levees. Its behavior in the delta soils, decidedly unstable in wet fill, will be watched with interest.

Dragline Excavators—More earth for levee construction is handled by dragline excavators than by any other device for constructing dumped dry fill. There is also in use every size of dragline from the little crawler with a 45-ft. boom to machines with 125-ft. to 150-ft. booms, variously mounted for self-propulsion.

In their use there is a measure of geographical grouping, arising partly from differences in construction conditions and partly from accidents of practice. The operations of the Memphis and the Vicksburg districts exhibit an unusual concentration of small draglines; the shallow borrowpits and common requirement for a haul call for draglines to load cars and wagons and for placement, while on the extensive hydraulic-fill work they are needed for dike-building and topping-off operations. For the same reason the large dragline is less used. In the New Orleans district, on the other hand, the different conditions of deep borrowpits and near-by material are favorable to large draglines, and there is a concentration in this district of 125-ft. to 150-ft. boom machines.

There is very little to be said of the small dragline that is peculiar to levee work. In loading cars and wagons, in dike building and even in topping off levee it is doing exactly the work it has long done in general earthmoving. There are many vagaries in sizes: Buckets range from ¾ to 1¼ yd. and boom lengths from 45 ft. to 80 ft. Many operations indicate a lack of co-ordination of the dragline size and capacity with the task to which the machine is put.

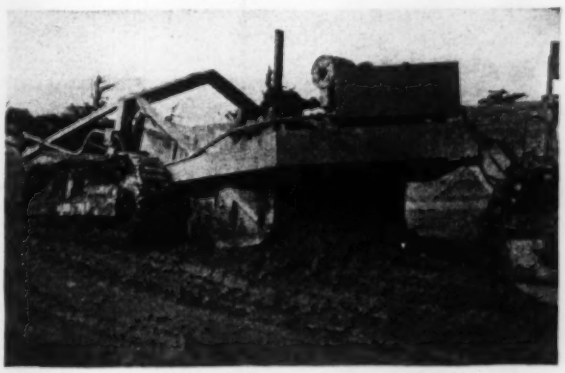
The smaller draglines are of many makes, are universally crawler mounted, and have gasoline engine power. In general they are standard factory product, which in some cases has proved less strong and durable than required by the grueling work to which they are put on the river.

Large draglines show a distinct tendency toward increased size; the new larger levee section required greater boom lengths, and recent machines have 150-ft. booms. At the moment there appears to be little disposition actually to install larger draglines, but much thought is being given to the possibilities of 175-ft. machines. The problem is one of integrating between the load that it is practicable to put on the ground and the volume of rehandling that it is possible to eliminate. The problem is highly complex and probably only an empirical solution can be expected.

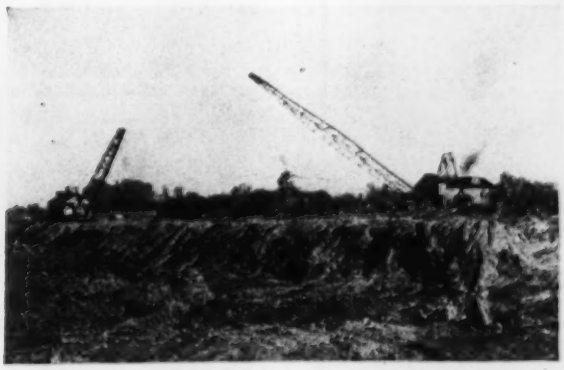
Machine mounting and mobility are the critical factors in larger dragline development. At present there are four types of mountings: skids and rollers (virtually obsolete), trucks and track, crawler tractions and walking tractions. Of the latest 150-ft. boom machines some have truck-and-track mounts and some walking tractions.

In respect to mobility the truck-and-track mount is more inflexible in direction of movement than the others, which are almost as facile in shifting toward or away from the fill as in shifting parallel to it. In respect to load concentration the truck-and-track mount with its four-point support is presumed to be at some disadvantage which is not fully offset by stiffness of track structure. Theoretically the crawler and walking tractions provide distribution of load by their own structure alone, but in soft ground corduroying is necessary, largely to furnish traction pull but also to distribute load. In respect to tracking, the trucks on rails give an ease of movement which the crawler and the walking tractions give only on very hard ground. So the comparison goes on, exhaustive and exhausting in its detail. The situation is that the mobile support of a 325- or a 350-ton machine on the Mississippi delta soils is one of the most intractable problems which the levee engineer and equipment builder have to solve.

The objective in dragline operation is to place directly as large a part of the levee as is possible. With the present large section some part of the fill must be rehandled between borrowpit and levee—this portion is seldom much less than 30 per cent and may reach 50 per cent. One possibility of reducing these percentages is increase in size, as just indicated, and the other is a change in the method of working out the pit which is made possible by the increased maneuvering ability of crawler and walking tractions as compared with truck-and-track mounting. So far these changes from the



POWER-OPERATED WHEEL SCRAPER
This device, operated by a 75-tractor, consists of four telescoping sections which open out in taking on load and close up in discharging load.



TANDEM DRAGLINES IN SHALLOW BORROW
Dragline on left handles from back pit to spoilbank and the one on the right rehandles into the levee fill. Only back pit material is rehandled; remainder placed direct.

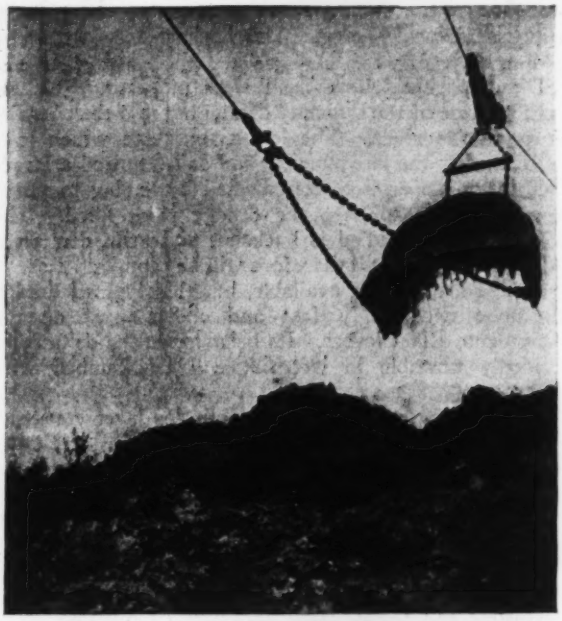
straight, parallel-cut method have not been satisfactorily worked out in the field.

Larger buckets have not followed increased boom length; 4-, 5- and 6-yd. buckets are used with 110-, 125-, 135- and 150-ft. booms, apparently without much regard to reach. In power plant there are more indications of change. The larger machines are being more commonly equipped with diesel engines, but the new power is not everywhere accepted; three of the eight 150-ft. boom draglines operating in the New Orleans River District have steam power—and also, it is interesting to note, have truck-and-track mounts. There is still reluctance to abandon steam despite its drawbacks of fuel servicing and water troubles. On one operation observed, the contractor had installed a diesel-electric unit and was emphatic in his claim of quicker pick-up of power, as compared with straight diesel transmission.

Slackline Cableway Excavators—The slackline cableway is second only to the dragline as a single-unit levee-building device. Most of the machines in operation have been some years in service. They have steam power and most of them have crawler traction, but some have the original truck-and-track mounts. All were designed for the old M.R.C. levee section, which is smaller than the superflood section now being constructed.

The present machines do not operate to the best advantage on the new large levee section. Consequently their use this year presents changes in procedure and is prompting thought of possible further development of machines and methods. In most operation this year rehaul is necessary to return the bucket to the back-pit zone. The present head-tower height is not enough to insure a gravity run-back. In the Memphis District the engineers have increased the height of the head towers to 97 ft. by framing a 25-ft. extension onto the old tower. It is believed that still higher towers are possible on the present machines, if they are built from the platform up.

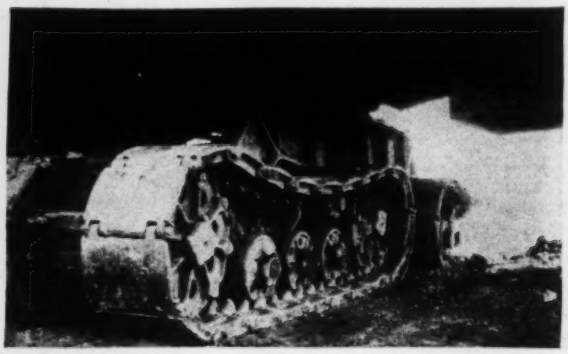
Tower excavators are being operated on spans considerably greater than have previously been common, but no longer than have been operated occasionally in the past. A 700-ft. span is frequently used and on occasion a 750-ft. span. With existing outfits the span can be run up to 800 ft. and possibly more in favorable locations and still continue present outputs. This span can be increased by heightening the head tower and decreasing the size of bucket, but outputs will be reduced. With larger power units and stronger head-tower equipment, there are further span-lengthening possibilities. Just where the cost of outfit and the possible output will place the economic limit is not agreed on by river engineers. As to bucket design, bottomless buckets have been tried this year on a few operations with encouraging results.



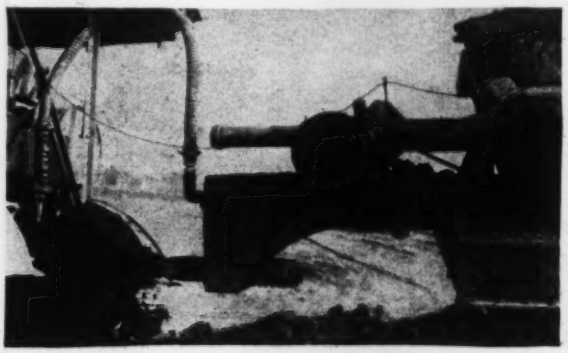
BOTTOMLESS BUCKET FOR CABLEWAY EXCAVATOR
The bucket, shown just after dropping its load, is virtually a crescent-shaped scraper holding practically no earth when lifted clear of the ground.

Thought is being given to the substitution of diesel units as the requirement for power unit replacement arises and in new machines diesel or diesel-electric equipment seems certain. Plans are also being considered for electric equipment on the head tower with current supplied by a diesel-generator field station located at some convenient central point on the operation.

Industrial Railway Haulage—Industrial railway haulage has been developed in a constructive way for general levee building by only one operator, who has secured patents on his process. In its ideal form it consists of a loop track with the long axis of the loop parallel to levee and borrowpit, one long side of the loop being within the levee area and the other being just within the borrow area (see p. 234). On the borrow side a train is loaded by dragline, and, traveling to the levee side,



CRAWLER TRACTION FOR CABLEWAY EXCAVATOR
Most of these excavators owned by the government and mounted on trucks for travel on rails have been changed to crawler traction.



TRACTOR-WAGON COUPLING AND DUMP
Tongue couplings of crawler wagons to tractors are universal. This particular coupling also carries a hydraulic mechanism for the doors.

dumps into a trackside pit or trench from which the material is rehandled by dragline into the levee fill. As the borrowpit is dug out, the loop track is widened out into the borrow area until all the material necessary for the levee fill is obtained. In practice this ideal plan is modified as local conditions make advisable; frequently the loop becomes a spur with passing tracks. Ordinarily two trains are operated, one being loaded as the other is being dumped.

As many loop units are installed as the contractor may deem necessary to complete his operation in the contract period or any less time considered more economical. On the work this year trains of five to twelve cars of 4 to 6 cu.yd. are operated by 4-ton gasoline locomotives. The draglines are diesel or gasoline powered, have crawler tractions and have booms 50, 60, 70 and 80 ft. long. Generally the long-boom machines are used in placing the fill. In the year's operations it is manifest that the industrial railway system is in the process of being worked out to disclose best-suited procedure and equipment.

Tractor and Crawler Wagon Work—Tractor and crawler wagons are the development of two seasons on the river levees. In this time they have improved enormously in mechanical perfection and general fitness, and, particularly with the elevating grader as a loading unit, they exhibit an advance in equipment development which is not surpassed by any other equipment.

The standard levee tractor is a 60-hp. crawler traction machine. Larger tractors, 75 and 100 hp., are being used, but only occasionally for special excavating devices. The 60-hp. tractor is, according to the year's experience, at about the lower limit of size economical with crawler wagon haul and for pulling elevating graders. The trend of requirement is toward more power; a 75-tractor is the probable future unit. The requirement is also for more sturdy construction and especially for crawler design and construction which guards the working parts better from sand and dust and gives longer wear to the tracking elements. The delta soils, the twenty-hour operation and the rough tracking and steep grades put a heavy burden on tractor structure and mechanism.

Crawler wagons are largely 7-yd. four-wheel wagons (two rear crawlers and two forward steel wheels on a swiveling axle), or 5-yd. cart wagons having two crawlers only. The direction of choice is toward the 5-yd. cart wagon. It permits of more compact design and more sturdy structure; with good tracking conditions two wagons can be coupled in train and hauled by a tractor, giving more yardage per trip than one 7-yd. wagon, and with a muddy pit one 5-yd. wagon can be hauled and keep pay dirt moving, whereas a much larger wagon cannot. The cart wagon maneuvers more easily, particularly in descending levee slope, where the front wheels of the four-wheel wagon are likely to jack-knife if the tractor operator is not careful.

In structure and general equipment the cart wagons of all makes are very similar. All have a tongue hitch with a vertical coupling pin. Chains and hand ratchets operate two-door dump bottoms, except in one make of wagon, which has a hydraulic dumping mechanism operated by electric-power take-off from the tractor. The construction of the crawlers varies with the make of wagon. In all cases they are the weak detail, poorly protected from sand and mud and going to pieces rapidly. Crawler maintenance and replacement are the large wagon upkeep expense.

Dragline excavators and elevating graders are employed for loading, the selection depending on pit conditions and contractor's practice. The dragline has an advantage in a pit that has been wooded, since it can handle roots and stumps. A more important advantage is that it works from the surface and loads wagons on the surface, which eliminates hauling over a wet pit bottom. The machines are the standard commercial product, and a sturdier machine generally is needed for the hard work required.

When favorable conditions exist, the elevating grader is proving to be a mighty efficient loading unit. As improved by separate power drive for the loading belt and by heavier construction, it has about double the output of the older axle-drive machine. Separate belt power is provided, either by an independent power unit on the grader or by a power take-off from the tractor. Recent tractor-grader outfits on the river are a beautifully co-ordinated excavating and wagon-loading mechanism. They have rejuvenated an old levee-building method, supposed to be falling into a decline, into a virile competitor for front-rank position among earth-moving processes.

Experimental Machines—Courageous development of experimental devices has been a significant feature of the year's work. Some of these are new inventions; others are old devices used on the Mississippi levee for the first time. Among the experimental machines for dry fill a power-fresno scraper is of leading interest because of the levee actually constructed. Other machines that have been barely tried, and one or two that have not been put into service, are held for consideration when something definite can be said of them.

WHEEL SCRAPER DRESSING LEVEE FILL
Much levee in the past was built with these outfits now used only for dressing fill, building crossovers and doing other odd jobs of earth moving.

BOGGED DOWN IN A SOFT SPOT
This is a rather good loam pit after a long dry spell, but groundwater is never deep and the pit bottom got too close to it and the crawler wagon "went in."

The Colorado River—

Economic Development of Its Basin

Water and Power the Key to the Growth of the Southwest—An Authoritative Statement of the Reasons That Led to the Great Boulder Dam Project

By Dr. Elwood Mead
Commissioner of Reclamation, Washington, D. C.

The water in and on the earth's surface is of constantly increasing importance to the life and comfort of man. As population increases and civilization advances so will the value of water increase and the struggle over its control will increase in like measure.

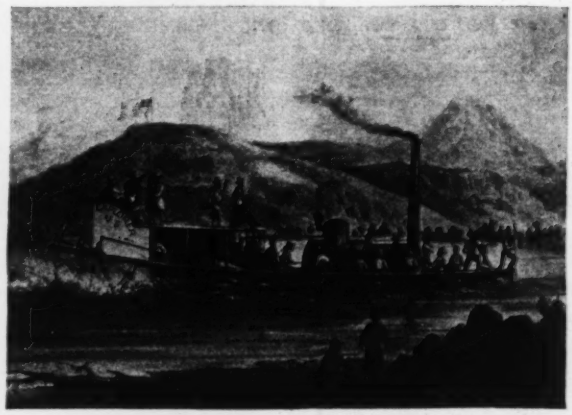
THIS philosophy of a text writer on water law illuminates the Colorado compact, framed to apportion the waters of the Colorado River among the seven states which form part of its watershed, and explains the bitter political war waged for seven years in Congress over the building of Boulder dam. With it as the central idea, let us follow the changing conceptions of the value of the river in the nearly 400 years after Cortez pawned his wife's jewels to send Francisco de Ulloa to find the fabled seven cities of Cibola. Ulloa reached mud-covered shores at the mouth of the river in 1536 and saw one of the great tides, which reach a height of 30 ft., rush, as he expressed it, "with a great rage into the land." For more than two centuries after his visit the Colorado continued to be of no use to the world.

Elwood Mead, authority on irrigation and land settlement, Purdue graduate of 1883, has been state engineer of Wyoming, irrigation adviser to the United States and many foreign countries, and creator of the California state land settlements. Chosen in 1924 to head the federal reclamation work.

Navigible Possibilities of the River

The early Spanish explorers valued the river as a means of reaching the interior. This was also the view of Lieutenant Ives of the Engineer Corps of the army when, in 1857, he sought to prove that the river could be made an artery of commerce to carry supplies to the military posts at Salt Lake and Tucson. If this were feasible, it would save 700 miles in the wagon haul to Salt Lake and 1,100 miles in the haul to Tucson. To attempt this he set up at the mouth of the river a steamboat which had been built in Philadelphia and carried in sections to the Gulf of California in the hold of a ship. The result was not encouraging. Starting in December, it was March when the swift current which rushes through the narrow gorge at Black Canyon made him accept this as the ultimate head of river commerce. He had good reason for so doing, as it took five days to travel the last 20 miles.

The early treaties between the United States and Mexico showed that both countries regarded navigation as the chief use of the Colorado River. They required Mexico to keep the river open to traffic between the mouth and the international boundary. It was not until the present century that this view was abandoned. At a recent conference of the International Water Commission of Mexico and the United States it was agreed that navigation had ceased to be of any practical importance. It could not be otherwise, because Mexico has sanctioned diversions aggregating 20,000 cu.ft. per second and has not objected to diversions which left the river a dry channel below the international boundary.



BOAT IN WHICH LIEUT. IVES TRAVELED UP THE COLORADO FROM ITS MOUTH TO BLACK CANYON
Ives report on Colorado River, 1861.

The Beginning of Irrigation

To the early dwellers along the lower Colorado there was nothing in the appearance a half-century ago of the low-lying brush-covered flats bordering the river to foreshadow the transformation that has come with the orange and date groves and the luxuriant gardens that greet the visitor today. Nor did the first attempts at irrigation give any indication of the immense importance rivers were soon to assume as creators of homes and of agricultural wealth. The pioneers took water as unconcernedly as they caught fish or shot game. They did not foresee the need of laws to protect their rights in doing this and opposed such laws when their enactment was sought. The boundaries of states ignored drainage lines. The value of water and the part it was to have in

shaping development and fixing the character of the future civilization of the arid region were undreamed of even by the wisest minds.

With this inadequate reference to the first 300 years of white exploration and development, let us turn to the economic conditions and legal problems which confront those seeking to create a foundation for a permanent and prosperous development in this river basin.

The Colorado has been described as the most talked about and least known river on the continent. It drains an area equal to the New England and Middle states with Ohio and Indiana added. Each state of the Colorado basin has farms irrigated from the river or its tributaries. Colorado leads, with 800,000 irrigated acres. Arizona is second, with over half a million acres. More than two and a half million acres are now being irrigated and more than seven million acres can be. To do this requires the reconciling of diverse water laws and of conflicting water rights. It requires financial aid which only the federal government can provide. The limits of private development have nearly been reached. These are the conditions which will confront the nation and the people of the basin when the new economic era is inaugurated by building Boulder dam.

SKETCH OF BLACK CANYON MADE BY LIEUT. IVES, 1857

The northern half of the basin is elevated, rising from 4,000 to 8,000 ft. The southern half is low, a part being below sea level. All the valleys are arid. In Wyoming the yearly rainfall varies from 10 to 14 in.; in parts of Arizona and California it is only 3 in. The southern end of the basin is the hottest and driest part of the United States.

All the water the river can furnish will be needed for irrigation, domestic and industrial uses. Its falling water will be used over and over again for the generation of power.

Growing Water Needs

Every state in the basin has plans for more irrigated acres, for more dams and storages. The known industrial and domestic needs are immeasurably greater than was thought possible a quarter of a centry ago. Denver, the capital of Colorado and on another river system, must look to the Colorado for the water to supply future homes and factories. Already one small tunnel brings water through the mountains from Colorado tributaries. A larger one will soon be equipped to do this and a longer one of greater capacity is regarded as an inevitable need of the future. The marvelous growth of the coast counties of southern California has created a need for more water than now falls on their whole watershed. More than 2,000,000 people now live there. Within the life of people now living, more than 5,000,000 will live there. The water for these added homes and factories must be brought from the Colorado. Able engineers are now studying the topography of eastern California to find the best route for an aqueduct which will bring from the Colorado River a million acre-feet of water a year to a score of coast cities, from Santa Barbara to San Diego.

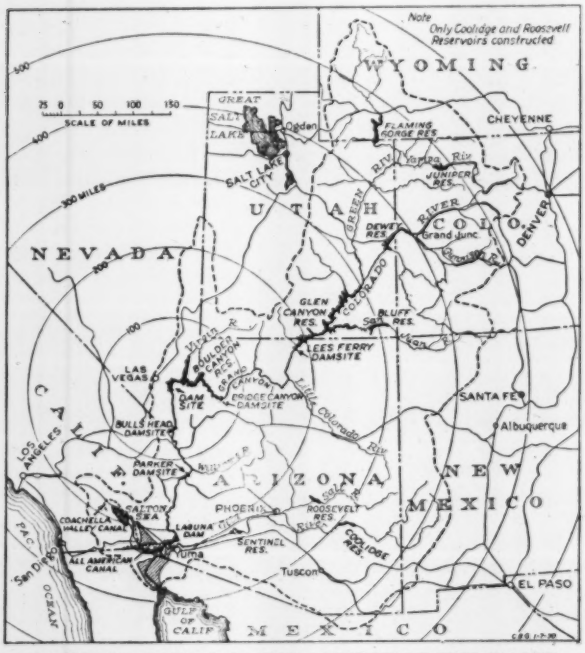
One does not need to look ahead a century to realize that the demands on the Colorado will in that time be far greater than its entire regulated discharge. The basin is rich in deposits of precious metals and useful minerals. Cheap power will do much to bring them into use. Nevada dreams of great mills hung on the canyon walls at Boulder dam. Utah hopes to see the industries of Salt Lake Valley duplicated along the Colorado. All the states are seeking, by political or economic maneuver, to enlarge their control over the stream.

Without regulation the lower river has little value. When the melting snows fill its thousands of little feeders, the lower river becomes a turbulent, dangerous force. Nearly a hundred miles of levees have to be maintained at great cost to keep the river floods from inundating the farms of Yuma and Imperial valleys. When the snows are gone, the river shrinks to a shadow of what it was two months before. The quick runoff of the river and the absence of summer rains accentuate this wide difference between the high and low water. The highest summer floods have exceeded 200,000 cu.ft. per second; low flow has dropped to 1,200 cu.ft. per second.

These conditions call for a large reservoir to regulate the river's flow as the next step in protecting development already made and in providing for its expansion. To serve all purposes the storage must be large enough to equalize the wide variation in monthly discharges and reduce the variation between years. The larger the storage the more valuable it will be.

Intensive Study Made of Sites

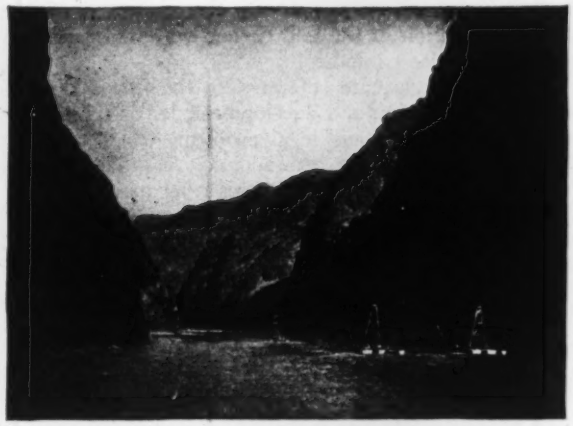
For twenty years the Reclamation Bureau studied the river to find the best storage site. Fifteen years ago I went over the problem with A. P. Davis, then director of the bureau. I was familiar with the upper part of the river because I had been assistant state engineer of Colorado and state engineer of Wyoming. I favored Flaming Gorge on Green River for the initial development. The cost is less, the engineering problems much simpler, but Mr. Davis said it was too far away from the irrigated fields of Arizona and California; that there were too many tributaries below to cause destructive floods. He urged that the lower the reservoir the more valuable it would be. Black Canyon is the lowest site for a deep reservoir of adequate capacity, and this fact



BOULDER CANYON IS THE LOWEST OF THE MAJOR DAMSITES ALONG THE COLORADO

led to its adoption. Before this site was definitely adopted, 70 different sites had been examined and finally a party spent three low-water seasons in the canyon testing the material of the bottleneck which the dam will close, as few sites anywhere have been tested.

While this study of the river was going on, canals to divert and use the river were being built in each of the seven states. In Wyoming the Big Sandy Canal brought under cultivation part of the land traversed by the Oregon trail. In Colorado the Reclamation Bureau built larger works to water the Uncompahgre and Grand valleys and at Yuma, and overcame grave engineering difficulties in constructing Laguna dam across the Colorado River, the siphon under the river, the canals to irrigate



DIAMOND DRILL OPERATIONS
Looking upstream through Black Canyon from Nevada side.

and the levees to protect 110,000 acres of land—located mainly in Arizona but in part in California.

The Delta and Imperial Valley

Meantime, private enterprise had undertaken a unique irrigation development. West of the Colorado and separated from it in the United States by a low ridge is a great basin with its lowest part 300 ft. below sea level. It was originally part of the Gulf of California, with the Colorado River emptying on its eastern side at about the present location of the international boundary between the United States and Mexico. Because of its rapid fall this river is a great carrier of silt. When in flood it has been described as a stream too thick to drink and too thin to plow. Every year it brings down enough mud to cover 100,000 acres or more a foot deep. In time it filled the Gulf of California and built up a deltaic ridge, which is now over 100 ft. above sea level at the international boundary and slopes west and south.

This ridge forms the southern rim of Imperial Valley. The river, flowing along it until it turns south to the Gulf, is kept out of the valley by a levee about 70 miles long. Below the river and below this levee is the Imperial Canal, which starts in the United States, crosses the international boundary, makes a loop through Mexico of about 60 miles and then returns to irrigate nearly half a million acres in southern California. When Mexico consented to the building and operation of this canal, it required that one-half of the water diverted should be supplied to Mexican irrigators if they desired it, and at present it supplies water to about 200,000 acres in Mexico and 450,000 acres in California. The difficulties of operating an international work are serious, and the people of Imperial Valley have long desired to escape them by building a much costlier canal, which will be wholly in American territory. Provision for this canal is made in the appropriation for Boulder dam and the Reclamation Bureau is now surveying it.

Seventy thousand people live under the Imperial Canal in California. They depend on it for the water that supports their immensely valuable agriculture, and they depend on the 70 miles of levee, all of which is in Mexico, to protect them from being inundated by the river floods. The difficulties of maintaining this levee become each year more acute. The great burden of silt carried down is being deposited near the lower end where the river spreads out over the deltaic plain. It is gradually building the bed of the river higher and higher, until

now the bottom of the river on the river side of the levee is 9 ft. higher than the land on the land side of the levee. Sooner or later some provision must be made for holding back this silt, and the great reservoir at Boulder dam will serve this purpose.

Complexities of Titles to Water

All the people who live in this great basin are bound together by their common tie of dependence on the river. Wherever they live the right to use its water in irrigation is far more valuable than the title to the land on which it is used. The determination of these water rights and their protection against conflicting rights or claims are far more difficult tasks than the establishment of land titles. The land is fixed. The water is here today and gone tomorrow. Coming from the melting snows, it fluctuates with every change of temperature and in every month of the irrigation period. Rights to the water which flows down the sides of Fremont's Peak into upper Green River are determined by Wyoming laws and it is diverted under the direction of Wyoming officials so long as it is within the boundaries of that state. When it passes into Utah it is subject to the laws of Utah, and in succession to those of Nevada, Arizona and California, and what is left when it passes beyond the international boundary belongs to Mexico.

The laws of six of these states are in harmony, in that they recognize the right to appropriate this water, take it out and apply it to beneficial uses on both riparian and non-riparian lands. The methods of determining how much water is beneficially used and the means employed to regulate diversions are not the same in each of the states, but they have a general agreement as to principles. California is different. That state has sought to retain the modified common-law doctrine of riparian rights and at the same time to enact and put into operation a code of laws recognizing appropriations by beneficial use. The doctrine of riparian rights is wholly unsuited to the conditions of an arid region, and the two rules of law can not co-exist without inevitable conflict. The benefits which come from the irrigation of non-riparian lands make the riparian doctrine war continually with the requirements of efficient development. Its operation in California has been another significant illustration of the truth of the adage that "A lie never ceases to do evil."

The Colorado Compact

When the building of a great storage work in the lower section of the stream began to be discussed, the upper states took alarm. It would enable those using the stored water to assert a right to all the unappropriated water above. It could not be asserted against existing uses, but would be a menace to future development. Especially was this true if power were combined with other uses in this regulation. All the water might not be used in irrigation, but all could be used to generate power.

To meet the united and vigorous opposition of the upper states, a conference of representatives of the seven states and the United States was held at Santa Fe, N. M., in 1922. Herbert Hoover, then Secretary of the Department of Commerce, was made the nation's representative and became chairman of the conference. An agreement was reached and a compact signed, which was submitted to the federal government and to the respective states for ratification. It was based on the assumption that the average yearly discharge of the river was somewhat in excess of 16,000,000 acre-ft. Of this, 7,500,000 acre-ft. were allotted to the four upper basin states, Wyoming, Colorado, Utah and New Mexico, 7,500,000 acre-ft. to the three lower basin states, Nevada, Arizona and California, with the right of the lower basin states to increase their consumptive beneficial use of such waters by 1,000,000 acre-ft. per annum.

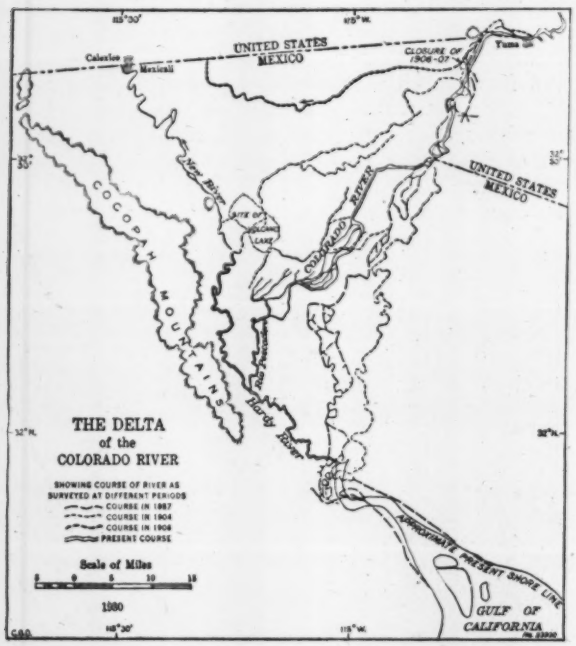
The Santa Fe conference faced a difficult problem, partly economic and partly political. The representatives of each state had to consider the political and economic views of those they represented. They had, in some way, to protect the upper states against earlier diversions and the establishment of prior rights on the lower part of the stream. This had to be anticipated, because the climate of the southern end of the basin gives greater value to water in irrigation. If filings already made on the stream were to be followed by construction, the northern states would find the water supplied by their mountains in use below before they were able to reclaim land susceptible of irrigation. As Colorado and Wyoming supply 80 per cent of the river's flow, this prospect was not pleasing to them.

All familiar with the plight of Imperial Valley knew that early construction of a reservoir was inevitable and that with such construction would come the establishment of prior rights to the stream which would endanger development in the upper states. To protect them from such danger the conference agreed to set aside, as be-

GREEN RIVER AS IT LEAVES THREE FORKS PARK
The three forks of the Green River come together at the base of the mountain in the middle distance.

tween these states, the doctrine of priority of right through appropriation and also the operation of the common-law riparian doctrine. In their place a scheme was devised of dividing the river to meet political and economic needs. This division has already been stated. So far as it is based on an understanding of existing uses and correctly forecasts future needs, it is a great advance on unplanned development and the accidental establishment of rights which goes with unplanned development.

To make the compact operate in harmony with actual conditions and necessities requires a thorough engineering and economic survey, to determine, as nearly as human foresight can, what are to be the future economic requirements of the different states. This survey should precede the division among the four upper states of the water allocated to them, and would have been better if it could have preceded the division by law of the water definitely allotted to the lower states. The need



THE DELTA OF THE COLORADO RIVER

for these studies is not confined to the Colorado basin. The Colorado compact has influenced the viewpoint of the people of every state in the arid region and threatens to make future development much more difficult because of the growing tendency to regard the water of a flowing stream as property to be disposed of by political or economic bargaining.

Six of the seven states ratified the compact. Thus far Arizona has not done so, though there have been a number of conferences of representatives of all the states and of the three lower states, in an effort to reach an agreement. The reasons for Arizona's refusal, as stated by Charles B. Ward, chairman of the Arizona Colorado River Commission, are:

> The reasons for Arizona's refusal to ratify the seven states compact were: First, Arizona objected to the inclusion of the Gila, and, second, while the prior appropriation doctrine would thereby be destroyed between the two basins by the allocation of waters to each of them, yet it would remain in full force and effect as between California and Arizona, and that while the upper basin states had escaped the danger which they had feared by California appropriating a great amount of water through the all-American canal that it intended to build, yet the same danger would still confront Arizona.

Boulder Dam

The Boulder dam act has a proviso that it should not become effective for six months after it was signed by the President. This was to give Arizona time to decide what action the state should take. None was taken except to renew objections to both compact and law, and the act became effective June 21, 1929.

The dam proposed will be between 675 and 700 ft. in height. The lake above it will be 115 miles long and will contain 26,000,000 to 29,000,000 acre-ft. of water, or enough to cover the State of Kentucky to a depth of 1 ft. It will hold the entire flow of the river for a year and a half and thus make possible equalizing the flow of the river in different years, and the generation of a large amount of firm power. This power will have an economic value of its own. One-half of it will be needed to pump the water required by the coast counties of California over the divide that separates the drainage of the Colorado from the coast. Cheap power will do much to develop the latent resources of the country surrounding the dam, and is needed to meet the wants of the rapidly growing population of Los Angeles and other coast cities.

There is only one satisfactory way to build the power plant, and that is to have a single power structure made a part of the dam. The bill was modified to provide for this, with three alternative plans for construction of the works and disposal of power. The first provided that the government should build the entire works, install and operate the machinery and sell the power at the switchboard; the second provided that the government should build the dam and that private interests should build the power plant, install the machinery and lease from the government the use of the falling water. The third scheme contemplates that the government should build the structures but that the lessees shall lease the power plant, or units of it, and operate the machinery.

Power Enters the Picture

During the months preceding the passage of the bill the original purpose of the act, which was to protect Imperial and Yuma valleys from floods and drought, extend the irrigated area in Arizona and California and furnish additional water for domestic and other uses in the coast counties of California, had been lost sight of. It had ceased to be a measure to provide water and had become, in the discussion and in popular opinion, a measure for the production and disposal of power.

Enlisted in this controversy were the private power interests, opposed to all government construction of power plants, the believers in state and municipal ownership and operation of power plants, and the different states which desired to participate in the power revenues. It became a struggle between different economic and social policies and for the political advantages of the different states. As a result the bill which was finally passed requires a Philadelphia lawyer to understand what it means, how far the Secretary of the Interior in the allocation of power is to be controlled by the preference given to municipalities and states, and how far he can exercise discretion in protecting the public welfare.

One thing the Secretary cannot ignore. The law requires him to secure a contract for the power that will repay the cost of certain parts of the works within 50 years. Without such contract the entire legislation falls

and Boulder dam will have to wait until Congress can deal with it again.

The Price of Power

An opinion widely held—that Boulder dam is being paid for out of taxation—is erroneous. It must be paid for out of power revenues and charges for storing water. The cost of the All-American canal, also made a part of this legislation, must be borne by the irrigators under that canal. After the Secretary has secured satisfactory contracts for power, he can then proceed to submit estimates for appropriations and make contracts for the building of the dam and power house.

On the Secretary of the Interior falls the difficult task of determining the price to be charged for this power and the price to be charged for storing water. He must charge a price high enough to repay the cost of the dam and power plant with interest within a period not exceeding 50 years, as required by the act, which further prescribes that such price shall be fixed with a view to securing a reasonable return, and may be adjusted at ten-year periods as justified by competitive conditions.

After a long and careful investigation the power experts employed by the department fixed a price for the power privilege at the dam of 1.63 mills per kilowatt-hour as meeting these requirements. Those who pay this price will have to install and operate the machinery. It is simply a means of fixing the price to be paid for falling water, with the government having nothing to do with the generation of hydro-electric energy. If the charge is much greater than this, customers can not be found. The city of Los Angeles and the coast counties of California might be constrained to pay more because of their overpowering need for water, which can be obtained only if the dam is built, but in other sections of the country the price to be paid for power would have to be on a competitive basis.

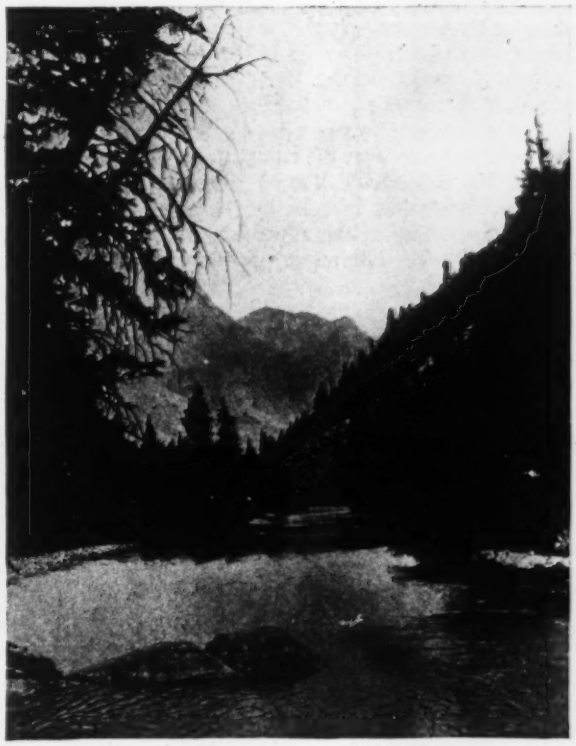
This price will make the cost of Colorado River power delivered in southern California somewhat greater than the present cost of generating power in the vicinity of Los Angeles by oil or natural gas, but all are agreed that this latter cost is likely to increase. While there have been protests that the price was excessive, two offers for the entire output have been received, one from the Southern California Edison and related companies, and one from the department of power and light of the city of Los Angeles. Both of these bidders are in a position to dispose of all the power purchased. There have been other offers, but the ability to dispose of the power is so problematical that the Secretary could not consider them with the facts now before him.

Proposed Power Contracts

The problem of disposing of the power is complicated by provisions in the bill giving to municipalities and to the three lower states of the basin a preference right to claim power. The act requires that this preference right of the states is to be exercised within six months. Only Nevada has indicated a desire to acquire any definite quantity of power. Certain municipalities in Arizona and California have also applied for power.

In dealing with these matters the Secretary has sought to dispose of the power primarily to the Southern California Edison and related companies and to the department of power and light of the city of Los Angeles. If this is done, the power will go into channels where power is now being distributed and will not cause any business disturbance.

There are, however, certain preference rights which must be protected. The Metropolitan Water District, comprising the southern California municipalities which are seeking a source of domestic water supply in the Colorado River, will need a large amount of power to pump this water over the mountains. A number of other municipalities have preference rights, as have the states of Arizona and Nevada. It is in every way desirable that these states be able to obtain this power whenever it can be utilized to operate mines or develop latent resources. The Secretary has been very successful in his negotiations with the different interests, in that he has induced the two principal distributors of power to agree that, while they will contract for (and if necessary take) all the power, they consent to the surrender to the Metropolitan Water District of one-half of the total amount of power generated, or so much thereof as may be necessary for pumping water in the aqueduct. They agree to surrender to each of the states of Nevada and Arizona 18 per cent, or 36 per cent of the total quantity



GREEN RIVER LOOKING UPSTREAM NEAR THREE FORKS, WYO.

of power generated, and to municipalities a certain additional percentage, the amount of which has not yet been definitely fixed.

If all these withdrawal privileges were exercised, it would mean that the original contractors would have less than 10 per cent of the power left to meet their requirements. They are willing to assume this risk because of a confident belief that not all the withdrawal rights will be exercised, or at least will not be exercised for many years.

If the power privilege is disposed of at 1.63 mills per kilowatt-hour, it will pay the entire cost of the dam and leave a very considerable surplus of money to be divided between the states of Arizona and Nevada, the bill providing for such division. It would appear that each of

these states stands to receive as an annuity somewhere between $350,000 and $700,000 a year.

Selling the Water

The price fixed by Secretary Wilbur for storing water for the coast cities of California is 25c. an acre-foot. This has been objected to as being too low, but those who object do not understand all the circumstances. Even this price will involve a payment by the Metropolitan Water District of $250,000 a year for a service that is merely nominal. It is all that should be required, and it is questionable whether any storage charge should be imposed. All the surveys thus far made of the aqueduct to carry water to the coast counties contemplate a diversion from the river below Boulder dam. It will take out water which has passed through the power wheels and for which a power toll of 75c. per acre-foot will have been charged. If it is not diverted, either it will go down to irrigation works which will divert it without paying any storage charge or it will go unused into Mexico. Filings for this water have been made, and the builders of the dam and reservoir cannot object to such diversions, even if no storage charge is paid, because the claimants would be entitled to take the water without payment during the greater part of the year as a part of the natural flow of the stream.

The willingness to pay a storage charge grows out of the imperative need of the cities for the building of these works, but this should not be taken advantage of to a greater extent than is done by the price fixed, because the immense cost of the aqueduct and the heavy yearly pumping charge will make payment for this water a serious burden on the households and industries of the coast. More money is not needed to get the revenues which the act requires.

If, however, the Metropolitan Water District changes its plans and diverts water above the dam or from the reservoir, a charge to compensate for the loss of power will be made.

Present and Future

Construction awaits the signing of contracts for power. Allocation of power has been postponed until after a conference of the three lower basin states at Reno, Nev., whose first sessions began on Jan. 20. It is hoped that at that time some of the objections of Arizona may be removed. It is not believed that this conference should seek to allocate now the 1,000,000 acre-ft. of water left subject to appropriation in the lower basin states. The 7,500,000 acre-ft. definitely apportioned among Arizona, California and Nevada provides for all immediate needs of the three states. Further action may well be postponed until the requirements of this region have been more definitely ascertained.

Everyone who has studied the Colorado realizes the imperative need of protecting Imperial and Yuma valleys from the menace of river floods. There is no safe basis of expansion but regulation of the river, which will give a larger water supply when the river is low. They recognize that the water problem of the coast counties of California is acute and that the benefits which the immense amount of cheap power will bring to the Southwest make this a development entitled to the confidence and support given it by the nation.

Sagebrush Desert in the Arid West

Rich Meadow Land Made From Desert

Date Palms Along the Lower Colorado

Water Is the Key to development of the West, Creating Wealth and Building Communities

Controlling the Colorado
—Engineering Plans and Construction

By Raymond F. Walter
Chief Engineer, U. S. Bureau of Reclamation, Denver

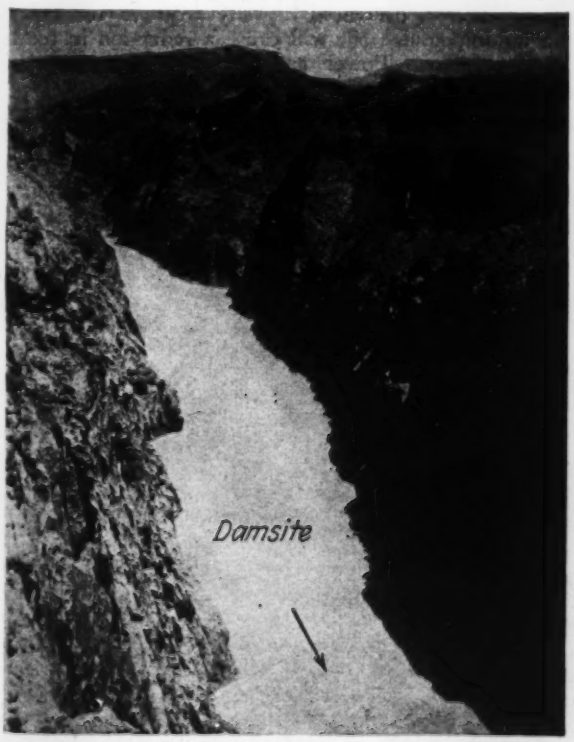
A Quarter-Million square miles send their waters down the Colorado, sometimes in great floods, sometimes in a dry summer trickle. To control these varying waters and save them not only for the dry seasons but for dry years, a storage dam nearly twice as high as the greatest ever attempted is to be built. Raymond F. Walter is intimately familiar with the exhaustive studies on which the planning of this huge structure is based. He briefs the facts in the terse language of an engineering report.

THE BOULDER CANYON project act (45 Stat., 1057), approved by the President Dec. 21, 1928, marked the end of an eight-year legislative fight and authorized, subject to future appropriations, the construction of a reservoir of not less than 20,000,000 acre-ft. capacity on the Colorado River, the dam to be located at either Black Canyon or Boulder Canyon. The purposes of the act in order of importance are (1) controlling floods, improving navigation and regulating the flow of the Colorado River; (2) storing and delivering stored water for reclamation of public lands and other beneficial uses within the United States; and (3) generating electrical energy as a means of making the project self-supporting. The act also authorizes the construction of the All-American Canal to divert water from the Colorado River at Laguna dam or other suitable point, and to deliver it to the Imperial and Coachella valleys, in California, the cost thereof to be returned to the government as provided in the reclamation law.

The U. S. Reclamation Service began its investigation of the Colorado River basin in 1904. After a prolonged study of the upper part of the main valley and principal tributaries, which study indicated a lack of necessary storage at reasonable cost, an investigation of storage sites in the lower river was begun. A preliminary examination of the problem and a reconnaissance of the river below the mouth of the Virgin was made, and as a result thereof work was concentrated on the better damsites in Boulder and Black canyons. Approximately half a million dollars was spent from 1918 to 1924 in foundation explorations at these canyons, in geological examinations and engineering studies of feasibility and cost of the Boulder Canyon project, and in studies of alternative projects for the fulfillment of the same functions. Activities preparatory to the development of final plans have been renewed during the past year in anticipation of the availability of construction funds in the near future.

Harris & Ewing Photo

Raymond F. Walter, graduate of Colorado Agricultural and Engineering College, 1893, has been an engineer in the U. S. Bureau of Reclamation for 27 years; chief engineer since 1924.



THE NARROW GORGE OF BLACK CANYON CREATES AN IDEAL SITE FOR BOULDER DAM

Congress, by joint resolution (45 Stat., 1011) of May, 1928, directed the Secretary of the Interior to appoint a board of five engineers and geologists to review the plans and estimates and report on the safety, economic and engineering feasibility, and adequacy of the plan presented. This board, called the Colorado River Board, consisting of Major-Gen. William L. Sibert, chairman, D. W. Mead and Robert Ridgway, consulting engineers, and W. J. Mead and Charles P. Berkey, consulting geologists, made a report on Nov. 24, 1928, published as House of Representatives Document No. 446, 70th Congress, Second Session. This report was generally favorable to the project and the plans submitted, the principal modification being a reduction in maximum allowable stress, a general increase in unit costs and an increase in river-diversion requirements for the construction period.

What Is Known of the River's Flow

Water Supply—Discharges of the Colorado River have been recorded at Yuma since 1902, at Topock since 1918, at Grand Canyon since 1923 and at Lees Ferry since 1921, all stations being operated by the U. S. Geological Survey except the Yuma station, which was operated by the Bureau of Reclamation prior to 1928. Records of

varying length are available for points on the main streams in the upper basin since 1895. From these data estimates have been prepared of the flow of Colorado River at Boulder Canyon for the 33-year period from 1897 to 1929, inclusive, and with upstream development as of years 1938 and 1988, these being the assumed years of completion of dam and power plant and the end of the 50-year repayment period contemplated in the Boulder Canyon project act. The following tabulation gives some general information regarding the annual use and flow of water:

	Original Condition	Condition as of 1938	Condition as of 1988
Upstream irrigated area, acres	0	2,040,000	3,368,000
Water used by upstream irrigation, acre-ft.	0	3,061,000	5,052,000
Transmountain diversions, acre-ft.	0	180,000	621,000
Reservoir evaporation, acre-ft.	0	240,000	920,000
Total depletion, acre-ft.	0	3,481,000	6,593,000
Average flow at Boulder Canyon, 1897-1928, acre-ft.	18,490,000	*15,009,000	*11,895,000

*Evaporation from Boulder Canyon reservoir, averaging 600,000 acre-ft., not deducted.

The Colorado River compact provides for an ultimate upper states depletion of 7,500,000 acre-ft. annually, less such allotment as may subsequently be made to Mexico out of the upper basin allocation. The ultimate depletion will therefore be greater than that of 1988, but since the project will be paid out that year the ultimate depletion is not of material interest at this time.

The Flood Problem

Flood Control—The storage required for flood control in order to reduce maximum river discharge to amounts which can be safely passed through the delta region has been based on the 1884 flood, the discharge of which has been estimated from a considerable mass of unrelated data consisting of reports of old residents, newspaper accounts, observations made during the construction of the Santa Fe Railroad bridge at Needles, and so forth. As a result of these researches the total flow of the Colorado River for the period from April to July, 1884, has been estimated at 30,000,000 acre-ft., a total 60 per cent greater than any flood occurring since that time. The maximum daily discharge for the 1884 flood has been estimated at 250,000 sec.-ft., which is but little higher than the corresponding maximum during the 1921 flood. Under 1938 conditions, the comparable total flow of the 1884 flood would be 25,500,000 acre-ft.

Flood estimates, based on studies of the relation between accumulated precipitation and flood flow, show that a part of the power storage can be used for flood-control purposes and that a considerable portion of the flood-control storage can be used for power production without material encroachment on the primary function of either. On this basis a storage reservation of 9,000,000 acre-ft. for flood-control purposes would reduce the maximum rate of discharge of an 1884 flood occurring in 1938 to a maximum reservoir outflow of 75,000 sec.-ft. without overtopping the dam, even though the reservoir was at flood level at the beginning of the year. Irrigation diversions and river loss would reduce this maximum flow to approximately 60,000 sec.-ft. in the delta region. On the same basis the highest flood since 1902 would be reduced to a maximum flow of about 30,000 sec.-ft. through the delta.

How the Storage Will Be Used

Irrigation and Power Storage—Estimates of annual streamflow at Boulder dam, with 1938 development and with runoff conditions similar to those of the period from 1896 to 1928, show the necessity for a large storage capacity in order to provide a comparatively uniform outflow suitable for irrigation and power requirements. Firm power output is controlled by conditions for a short period ending in 1904, at which time storage is depleted to the minimum compatible with allowable shortage of power and maximum power output over a series of years. The following table shows the derived results for conditions as of 1938 for three different heights of dam being tentatively studied at the present time:

Elevation at top of dam	1,207	1,225	1,232
Maximum water surface elevation	1,204	1,222	1,229
Raise in water surface, ft.	557	575	582
Reservoir capacity, acre-ft.	27,000,000	29,500,000	30,500,000
Flood-control reservoir, acre-ft.	9,500,000	9,500,000	9,500,000
Capacity for irrigation, power, and silt, acre-ft.	17,500,000	20,000,000	21,000,000
Continuous firm power output, hp*	610,000	650,000	665,000
Assumed installation, 65 per cent load factor for firm power, hp.	940,000	1,000,000	1,025,000
Computed mean power output, 1897 to 1929, hp.	837,000	884,000	900,000

*83 per cent plant efficiency and 10 per cent maximum shortage.

Similar computations have not yet been completed for the conditions that will exist in 1988. At that time upstream depletion will result in less water for power development and decreased capacity required for flood control. Impounded silt will cause a reduction in total storage capacity. Power and irrigation dams at the

THE RUGGED, BROKEN REGION SURROUNDING BLACK CANYON NECESSITATES THOROUGH PLANNING OF THE CONSTRUCTION WORK

Bulls Head and Parker sites, below Black Canyon, if built by that time, will regulate the outflow from the Boulder Canyon reservoir, thus leaving the Boulder Canyon project free to be operated primarily for power production, subject only to certain restrictions which will preclude the waste of waters that might be needed for irrigation purposes.

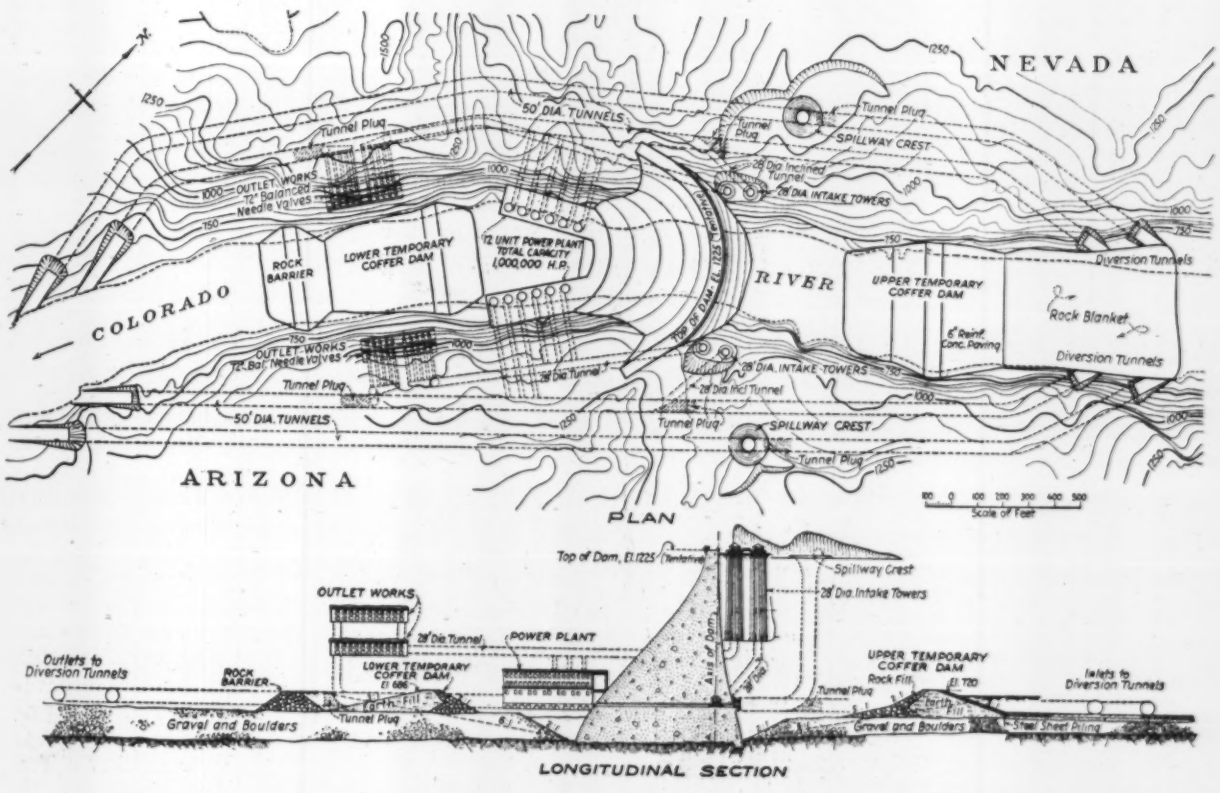
In view of the uncertainties in the discharge records, the effect of upstream depletion and reservoir silting and the possible occurrence of extended periods of low runoff with average flows less than those prevailing in the past 33 years, the financial set-up of the project must be based on a firm power output materially less than the indicated available firm power as of 1938. Consequently, firm power equivalent to 550,000 hp. continuous output is being considered.

Silt Storage—The Colorado River Board adopted 137,000 acre-ft. per annum as the best estimate of the rate of silt inflow to the reservoir. With the construction of upstream reservoirs, the quantity of silt reaching Boulder Canyon will be materially reduced. The Bridge Canyon dam, when built, will intercept the greater part of the present silt flow. It is estimated that the total silt deposits will not exceed 3,000,000 acre-ft. at the end of the 50-year repayment period, and such a deposition is being considered in the set-up. Deposits occurring after the end of the repayment period are not considered of immediate concern.

Boulder Canyon Reservoir—The reservoir formed by the proposed dam will be more than 100 miles long and will be the largest artificial body of water in the world. The greater part of the storage will be obtained in the valleys of the Virgin River and Las Vegas Wash on the Nevada side and in the Detrital Valley on the Arizona side. The upper end of the reservoir is a narrow canyon having comparatively little storage space. The major portion of the reservoir is a hilly basin of hard rock floored chiefly by gypsiferous silty beds of the Muddy Creek formation and to a less extent by coarser detrital deposits of the same or younger age. There is no evidence of the existence of any porous rock formations through which water might escape. Near the damsite the rock dips generally in a northeasterly direction away from the site so that the chance of leakage is small, since the water would have to find its way not merely between but across the rock flows. Thus it may be concluded that the reservoir will have no appreciable leakage.

Dimensions of the Dam

Damsite—The proposed dam will be located in Black Canyon about 25 miles southeast of Las Vegas, Nev., Black Canyon being about 20 miles downstream from Boulder Canyon. The site adopted is about 1½ miles below the upper end of the canyon. The rock formations in Black Canyon are volcanic flows and tuff-breccias, primarily of andesitic composition; the material exposed in the canyon walls, from the upper end to a point at least a quarter of a mile below the damsite, is mainly andesitic tuff-breccia. Although the formation is somewhat jointed, the rock is well cemented, tough, durable, impervious, and an excellent material for tunneling as well as for the foundations and abutments of a high dam. Some faults are exposed on the canyon walls near the damsite, but none of them shows any evidence of recent movement. Undisturbed potholes, crossed by faults, exist on the Arizona side, about 900 ft. above the river, thus indicating no movement along the faults during the period in which the river channel was lowered 900 ft. by erosion. These faults are not located so as to impair the safety of a high dam.



PLANS FOR BUILDING BOULDER DAM INVOLVE EARTH-FILL COFFERDAMS AND FOUR DIVERSION TUNNELS

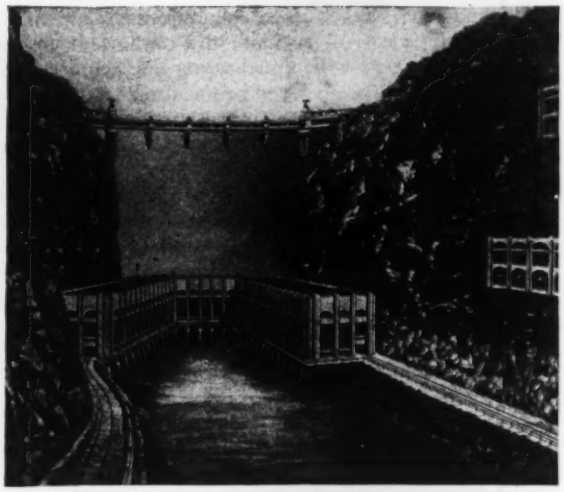
Boulder Dam—Boulder dam will be more than 700 ft. high and will contain approximately 3½ million cubic yards of concrete, of which about half a million yards will be below low-water surface, the lowest point of the base being approximately 125 ft. below low water. After the river is diverted and the foundation and abutment excavation is completed, the construction problem will be simply a huge mass-concrete manufacturing job, probably the largest ever undertaken, considering the vertical height and limited horizontal area involved. The time required to complete the mass concrete work is estimated at about two years and eight months.

The dam will be a curved gravity structure, designed for a maximum stress of 30 tons per square foot, as recommended by the Colorado River Board. The stresses in the section are being determined by the trial load method of analysis, the method developed in the Denver office of the Bureau of Reclamation during the past five years. The first stages in the development of this method were described in the *Transactions* of the American Society of Civil Engineers for 1929, in an article by C. H. Howell and the late A. C. Jaquith, entitled "Analysis of Arch Dams by the Trial Load Method."

The trial load method, as developed thus far, takes into account uplift at the base of the dam and within the concrete; radial sides of the cantilever elements; temperature changes in concrete, as produced by both setting heat and exterior air and water temperature variations; transverse shear in both arch and cantilever elements; tangential shear between the arches; the effect of twist; and the effect of foundation and abutment deformations in both arch and cantilever elements. Other problems being comprehensively investigated in connection with the design of Boulder dam are the effects of water-soaking of the concrete near the upstream face of the dam, flow of concrete, Poisson's ratio, variations in modulus of elasticity and the non-linear distribution of stress between the two faces of the dam. Although the studies are far from complete at the present time, the indications are that some of the above-mentioned effects, especially the last, are of relatively great importance in the design of so high a dam.

Plans for Outlet Works

Outlet Works—For the discharge and regulation of irrigation water it is proposed to install in both canyon walls needle valves connected by tunnels to the reservoir above the dam. Because of the unusual head of water, the needle valve is the most satisfactory method of regulating the outflow. Part of the needle valves will be connected to the inside diversion tunnels and the remainder to the penstock tunnels, but all valves will receive water through the power intake towers. The size of valves, size of feeder tunnels and total capacity of valves are tentative under the present scheme and may be materially altered when the final designs are completed. As now planned, the only openings through the dam will be the outlets at river level, for passing the low-water flow of the river while the diversion tunnels are being plugged.

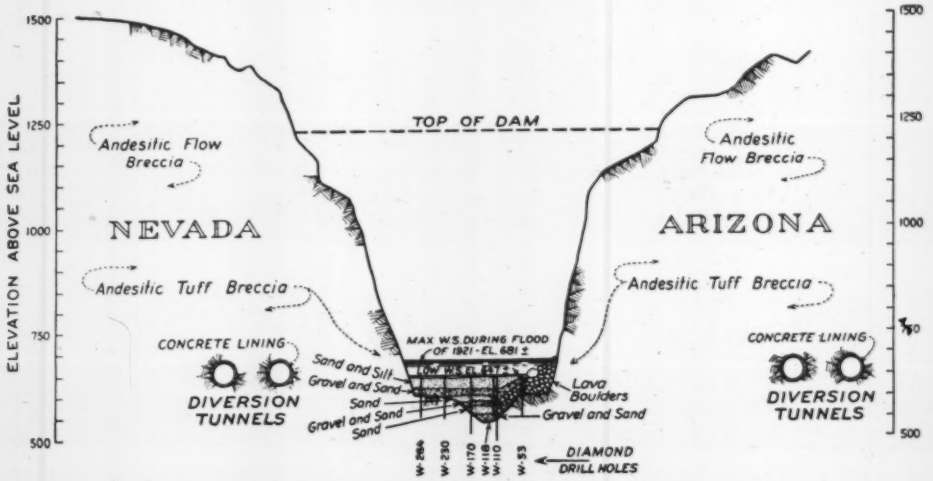


POWER HOUSES ON BOTH BANKS DIRECTLY BELOW DAM

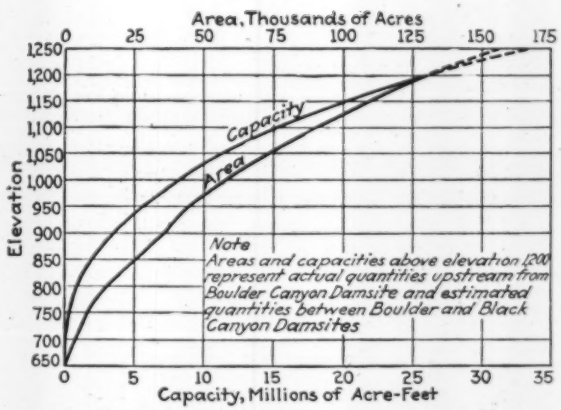
Spillway—Under the present plan of flood regulation a spillway of only nominal size would be required, but because of the location of the power plant, the great height of the dam and the damage which might result should an abnormally large flood overtop the dam, spillways of ample capacity will be provided. The exact type, location and maximum capacity have not been definitely determined. Further study and comprehensive model experiments will be required before final designs can be made. The interests of the delta region will be best served by limiting the flood discharge to a very nominal flow, but the safety of the dam and power plant demands that provision be made to prevent overtopping of the dam by any considerable depth of water.

The glory-hole type of spillway shown in the accompanying drawings discharges through 50-ft. diameter vertical shafts into the outside diversion tunnels. They are of ample capacity to discharge any flood that may be anticipated without overtopping the dam.

Power Plant—Tentative plans for the proposed power plant



PROFILE AT DAMSITE, LOOKING UPSTREAM
More than a hundred feet of excavation required to reach rock foundation.


Area, Thousands of Acres
0 25 50 75 100 125 150 175
Elevation
1250 1200 1150 1100 1050 1000 950 900 850 800 750 700 650
Capacity
Area
Note
Areas and capacities above elevation 1200 represent actual quantities upstream from Boulder Canyon Damsite and estimated quantities between Boulder and Black Canyon Damsites
0 5 10 15 20 25 30 35
Capacity, Millions of Acre-Feet

HOW THE SIZE OF THE BLACK CANYON RESERVOIR INCREASES WITH HEIGHT OF DAM

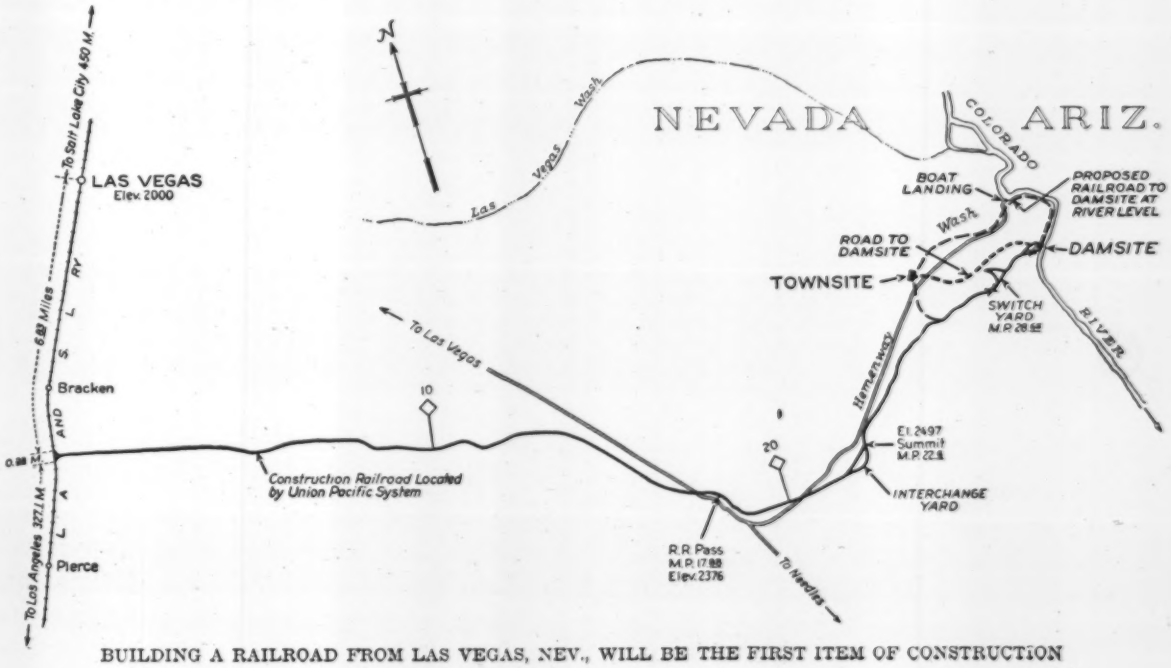
Raising the dam 25 ft. as now under consideration will produce more effective equalization of river flow and make larger amounts of power available.

contemplate an installation of approximately a million horsepower. The power plant will be located immediately below the dam, one-half on the Nevada side of the river and the other half on the Arizona side, forming a U-shaped structure with the base of the U resting on the downstream toe of the dam.

Two of the large diversion tunnels of the four which are to be excavated through the rock walls of the canyon for use in the construction period, each controlled by an intake tower equipped with shut-off gates and trash racks, will deliver water to the penstocks, which will connect with the turbines. Each pressure tunnel will serve a group of turbines independently of the others, which will make it possible to take any one of the pressure tunnels out of service for inspection or maintenance purposes without affecting the power output of the remaining 75 per cent of the plant capacity. Due to the value of the power generated, it is quite probable that storage of water and the operation of the plant will be started before the construction of the dam is finished and the project formally completed.

Construction Railroad—Access to the site and supply of materials and equipment constitute the most important preliminary problem of construction, now that river and rock conditions have been fully explored. Access will be from the north or right bank. Already the Union Pacific Railroad Co. has located a construction railroad from a point on the main line about 7 miles southwest of Las Vegas, Nev., following an easterly course and ascending on easy grades to the Interchange Yard, thence, descending on comparatively steep grades, as high as 5.12 per cent, to the top of the canyon wall at the damsite. At the Interchange Yard the usual type of locomotive will be changed for one adapted to the heavy grades beyond. Just before reaching the damsite the railroad crosses Hemenway Wash, an area about 10 miles long and 2 miles wide, having a rather uniform slope of about 4.5 per cent, from which the concrete aggregates will probably be obtained and near which the permanent town will be built. The accompanying map shows the construction railroad; also a tentative location of a proposed railroad down Hemenway Wash and along the river to the damsite, for use in transporting tunnel muck, foundation excavation and cofferdam materials. A survey of a switchback line from the switchyard to the river level below the damsite was made by the Union Pacific engineers, but because of the excessive cost an inclined railroad will probably be built from the canyon rim to the river level below the power plant as a permanent means of access to the plant.

River Diversion—The plan of river diversion being considered at the present time contemplates upstream and downstream cofferdams with diversion tunnels on both sides of the river designed for a maximum diversion capacity of 200,000 sec.-ft. as recommended by the Colorado River Board, the tunnels to be utilized as power and spillway conduits after the dam is completed. Different heights of cofferdam and various numbers and sizes of diversion tunnels are being considered, the indications at present being that four tunnels with diameters somewhere between 35 and 50 ft. will ultimately be adopted. In view of the excellent character of rock in the canyon

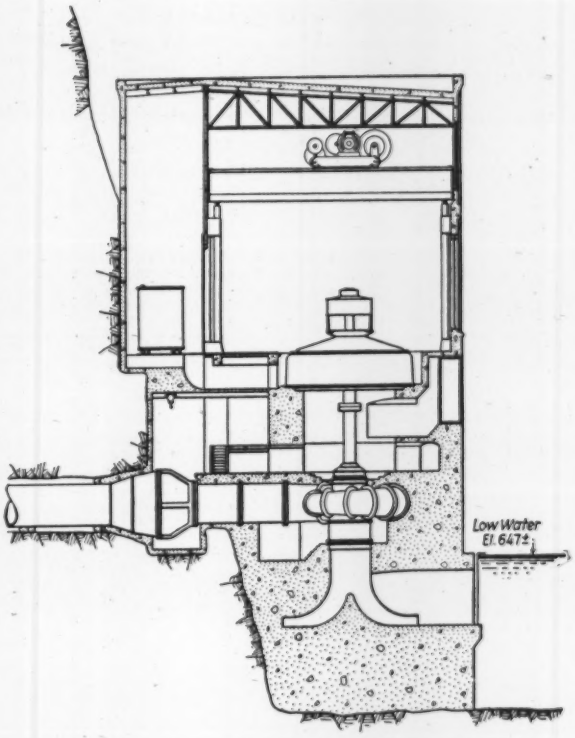


BUILDING A RAILROAD FROM LAS VEGAS, NEV., WILL BE THE FIRST ITEM OF CONSTRUCTION

walls, the driving of the tunnels probably will not involve particularly difficult problems. Tunnels of larger size have been successfully driven (see *Engineering News-Record*, Nov. 25, 1920, p. 1046). The time required to drive the tunnels is the most important factor in their construction, since any appreciable delay in completion would postpone the diversion of the river for an additional year. The river must be diverted immediately after the passage of the summer flood in order to provide sufficient time for the construction of the cofferdams before the next flood season arrives.

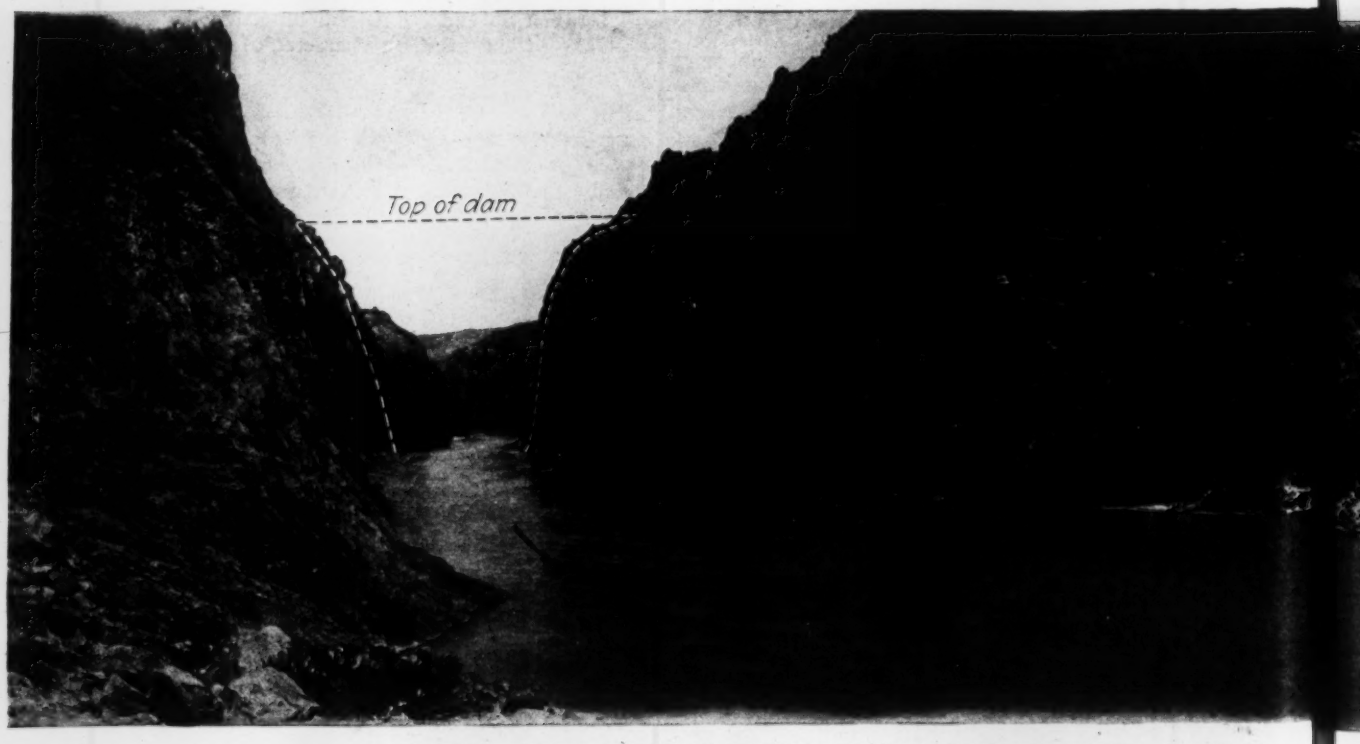
Sequence of Construction—Before work can be started at the damsite it will be necessary to build the construction railroad, to provide adequate housing facilities and to secure electric power for construction purposes. The first step in the program will be the construction of the railroad. The next step will be the building of a complete town with all modern improvements, including sewer and water-supply systems, the water supply being obtained from the Colorado River. Construction of a temporary power plant, or of a transmission line from some outside power source, can proceed simultaneously with the building of the railroad and the town.

As soon as transportation, housing and power facilities are available, the driving of diversion tunnels will be started. On completion of the tunnels, the river will be diverted and the upstream and downstream cofferdams built so that the foundation for the dam can be unwatered and the foundation excavation made. Stripping of loose rock on the canyon walls, excavation of highway approaches and such abutment excavation as may be required will be carried on while the cofferdams are being built. As soon as the foundation excavation is made, pouring of mass concrete will be started. Concrete work in the spillway, power tunnels and outlet works can proceed simultaneously with the pouring of mass concrete in the dam. It is estimated that all work can be completed within seven years.



POWER HOUSE TURBINES SUPPLIED FROM DIVERSION TUNNEL; DISCHARGE TO RIVER

The construction of the main line of the All-American Canal will be a six-year program and the work can proceed simultaneously with the construction of the dam. No estimates of the time required to build the Coachella branch of the All-American Canal have been made thus far.



OUTLINING THE 550-FOOT DAM AGAINST THE WALLS OF BLACK CANYON AS SEEN IN

All-American Canal—The construction of the All-American Canal is needed because of international problems involved in the distribution of Colorado River water, in order to develop higher irrigable areas in the Imperial and Coachella valleys and to serve as an aid in solving silt-removal problems. The canal will run in a southwesterly direction, generally parallel to the Colorado River, to the international boundary line, thence in a westerly direction and at varying distances north of the boundary to a point about 10 miles west of Calexico, Calif. The total length of this section of the canal will be between 75 and 80 miles, depending on the diversion point selected. Present studies contemplate a maximum canal capacity of 15,000 sec.-ft. Power can be developed at various sites along the route of the canal, principally at Siphon Drop, Pilot Knob and possibly three or four places west of the sand hills. The Coachella branch diverts from the main canal at a point about 40 miles from Laguna dam, runs northwesterly to a point near Indio, Calif., northwest of the Salton Sea, and thence southerly to a point near the northern boundary of Salton Sea, the length of this branch being about 140 miles.

The sandhill area, which must be crossed by the canal, begins about 10 miles west of Yuma and is about 10 miles wide. The canal will cross this area in cuts of comparatively great depth, the maximum being about 100 to 120 ft., depending on the diversion site selected. The sand is relatively fine, locally known as "blow sand" and is moved by wind velocities as low as 10 miles an hour. Since the deposition of this material on irrigated lands is not desirable, some means of keeping it out of the canal or of removing it from the canal flow must be devised. Silt in the river flow will be removed so far as practicable at the point of diversion.

Several locations above Laguna dam, as well as at Laguna, for diversion are being considered. If diversion is made at Laguna, some reconstruction of the dam will be necessary in order to obtain a higher diversion level. Upstream diversions have the advantage of making more head available for maintaining canal flow and for power development, as well as permitting reductions in the comparatively great depths of excavation required through the sandhill area. Although none of the sites above Laguna has been adequately investigated thus far, it is practically certain that rock suitable for the foundation of a concrete gravity dam will not be encountered at a reasonable depth at any of the sites and that consequently the so-called floating type of structure will have to be constructed. At one or more of the sites being considered rock is available on the diversion side of the river to serve as a foundation for the headworks structure. Rock is also encountered at three or four locations along the canal route.

The excavation and disposal of materials along the canal is a problem that is being given careful consideration. It is possible that great economies may be effected by the development and use of equipment not now in general use. There is no precedent in this country for a canal as large as the one being considered, the Imperial Canal, which has less than one-half the capacity of the proposed All-American Canal, being the largest now in operation in this country.

What the Project Will Cost

Cost—The cost of the Boulder Canyon project as estimated by the Colorado River Board, assuming a construction period of seven years, will be as follows:

Dam and reservoir (26,000,000 acre-ft.)	$70,600,000
1,000,000-hp. development	38,200,000
All-American Canal	38,500,000
Interest on above, during construction	17,700,000
Total	$165,000,000
Additional needed for Coachella Canal	$11,000,000

A total expenditure of $165,000,000, subject to subsequent appropriation acts, is provided for in the Boulder Canyon act. The construction of the Coachella branch of the All-American Canal may require additional authorization and appropriations of approximately $11,000,000.

PANORAMIC VIEW GIVES AN IMPRESSION OF THE GREAT SIZE OF THE UNDERTAKING

Huddleston Photo Co., Los Angeles

Present Status of Major Engineering Projects

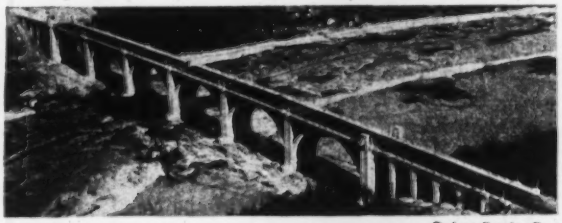
Highway and Railroad Bridges

Fort Lee Bridge—On Feb. 1 cable spinning on the 3,500-ft. Hudson River suspension bridge between 178th St., Manhattan, and Fort Lee, N. J., involving the simultaneous stringing of wires for four 36-in. cables, was approximately 20 per cent completed. The two main towers, which were erected up to five-sixths of their total height of 600 ft. when work was discontinued for the winter 1928-29, were completed in 1929; in July erection of the footwalks was begun; and cable spinning commenced in October. Previous to this, work on the New Jersey anchorage shaft and approach cut was finished in May and concrete in both the anchorages was completed during the spring months. Demolition work incident to construction of the Manhattan approach to the bridge is now about 50 per cent complete. The bridge is being built by the Port of New York Authority and is expected to be open to toll-paying traffic in 1932.

Kill van Kull Arch—Erection of steel on the two-hinged open-spandrel Kill van Kull arch highway bridge of 1,675-ft. span connecting Bayonne, N. J., with Staten Island, New York City, was begun last fall. On Feb. 1 six panels had been erected on the south end. Steel erection from the north will not be commenced until completion of the south end, which requires the erection of eight more panels. The arch abutments were completed about Aug. 1 and steel erection was begun shortly thereafter. The concrete approach piers on the Bayonne side were finished in January of this year, while the approach piers on the Staten Island side were completed last fall. Steel girder erection on the Bayonne approach, about a two months' job, has just begun. The structural steel for the Staten Island approach is being utilized as falsework during main span erection, so that this approach will be the last division of the project completed. The bridge is being built by the Port of New York Authority to be operated on a toll-refunding basis. The steelwork is scheduled for completion April 1, 1931.

Mid-Hudson Bridge—Spinning of the two 16½-in. cables of the Mid-Hudson highway suspension bridge at Poughkeepsie, N. Y., commenced Dec. 2 and will be completed by March 1. Present plans contemplate opening of the bridge to traffic by Labor Day of this year. The bridge, which has a center span of 1,500 ft. and side spans of 750 ft. each, is being built by the State of New York and will be operated on a toll basis until paid for.

Washington Bridge, Providence, R. I.—Construction of the Washington bridge across the Seekonk River between Providence and East Providence has advanced so rapidly during the past year that the contract completion date, October, 1930, probably will be anticipated by several months. Only a small percentage of the 80,000 yd. of concrete in the structure remains to be poured, and the remaining work consists largely of finishing items. The total length of the project is 2,407 ft., consisting of twelve concrete arches and a double-leaf bascule span. The approaches consist of earth-fills between two heavy concrete retaining walls. Other



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MULTIPLE-ARCH HIGHWAY BRIDGE OVER RARITAN RIVER NEAR NEW BRUNSWICK, N. J.

quantities involved in the project are 3,380,000 lb. of reinforcing steel, 12,000 wooden piles and 400 concrete piles.

Maumee Suspension Bridge, Toledo—Contracts were awarded during the year for a suspension bridge across the Maumee River at Toledo, Ohio, with a 785-ft. main span and an over-all length, including approach structures exclusive of embankments, of 3,215 ft. At the present time the approach piers are 60 per cent completed and work is under way on the anchorages and main piers, the latter being about 40 per cent completed. A considerable portion of the structural steel has already been fabricated and it is contemplated that steel erection will begin about March 1. The bridge is being built by the city of Toledo to be operated as a free structure, and is scheduled for final completion in December, 1930.

Vicksburg Bridge—Erection of the steel superstructure is nearly completed on the combined railroad and highway bridge being built across the Mississippi River at Vicksburg, Miss., the first structure over the river between Memphis and the Gulf, a distance of 850 miles. The main river crossing consists of a cantilever truss structure with a center span of 825 ft. and anchor arms of 420 ft., and three simple truss spans of 422 ft. each. All of the steelwork has been erected except the center span of the cantilever. The west approach, consisting of a steel trestle 4,110 ft. long, carrying both the highway and the railway, and an embankment and timber trestle 3,600 ft. long, is complete. Short steel trestle approaches on the east are finished except for the concrete deck on the highway trestle. Pouring floor slabs on the main span is progressing along with the steel erection.

Bridges at New Orleans—Of the two free bridges being built by the Louisiana State Highway Department at the lower end of Lake Pontchartrain to provide access to New Orleans from the east, one, the Chef Menteur bridge, was opened to traffic Sept. 11. The second structure, across Rigolets Pass, is about 95 per cent completed. It consists of two 250-ft. through steel trusses and one 270-ft. swing span, with concrete pile trestle approaches at each end.

After rejecting plans for a proposed highway bridge across the Mississippi River from New Orleans to Gretna, La., the U. S. War Department reconsidered its action and, on Jan. 27 of this year, approved revised plans for a cantilever bridge at this location. The original plan for a suspension structure was abandoned because of anticipated difficulties in providing suitable anchorages for the cables.

Columbia-Wrightsville Concrete Bridge—Work on the river section of this 28-span structure has been suspended until after the spring floods, and the temporary construction trestle from which operations were being conducted has been

AMBASSADOR SUSPENSION BRIDGE CONNECTING DETROIT, MICH., AND WINDSOR, ONT.

removed in anticipation of ice jams, which are unusually severe in this portion of the Susquehanna River. At the time of suspension all foundation work had been completed and approximately one-half of the arch rings had been poured. The structure has a total length of 7,374 ft., with a 38-ft. roadway and a 6-ft. sidewalk.

Southern Pacific Suisun Bay Bridge—Foundation work is more than half completed and progress is being made according to schedule on the double-track railroad bridge 6,000 ft. long being built by the Southern Pacific to replace the present train-ferry across an arm of San Francisco Bay. Pier foundations for the 530-ft. main spans are being sunk as 40x60-ft. open caissons; the internal dredging method is used to put them down to rock 140 ft. below low water. The main spans have a clearance of 70 ft. above high water and one lift span will provide clearance of 135 ft. over the channel. The caissons are built on sand islands made by sinking 80-ft. diameter steel shells into mud bottom and filling them with sand. Steelwork will total 22,000 tons and extensive use is made of silicon steel and heat-treated eye-bars. Erection of the steelwork had commenced before the end of the year and completion of the $12,000,000 structure is expected in February, 1931.

Longview Bridge — The privately owned highway toll bridge across the Columbia River between Rainier, Ore., and Longview, Wash., was not completed by the first of the year as the construction schedule required, erection of the steel, which totaled 12,870 tons, having been delayed by extreme weather conditions. On Jan. 22, 1930, it was estimated that ten more working days would suffice to pin the suspended span in place, after which the concrete floor slab on the channel span would remain to be placed. Vessiculated lava aggregate was obtained for the concrete floor slab so that the weight could be kept to a minimum. The bridge includes a 1,200-ft. main channel span (built out from both ends as a cantilever) flanked by 760-ft. anchor arms. Mid-channel clearance above low water is 192½ ft. Long timber approaches on both ends are separated from the steel portion of the structure by fire safety spans 28 ft. long which are intended to fall, giving protection to the main bridge, in case of fire on the approaches.

St. Johns Bridge, Portland, Ore.—A rope-strand cable suspension bridge with a main span of 1,207 ft. connecting two parts of the city of Portland, Ore., now separated by the Willamette River, was begun during 1929. It is the longest suspension bridge for which rope-strand cables have been utilized and is known as the St. Johns bridge. At the present time all concrete work below ground on the approaches is completed. The concrete abutment and two concrete piers on the east side have also been completed. Excavation for the two main piers has just been finished and the crib is placed for the east pier. Concrete piles have been driven for the east anchorage. The steel contract has been awarded and a considerable amount of steel is fabricated.

Sydney Harbor Bridge—The 1,650-ft. steel arch bridge over the harbor at Sydney, Australia, has been progressing recently at the rate of about two panels per month. Of the 15,000 tons of steel required in each half of the main span, about 10,000 tons is erected on the south side and 4,000 tons on the north side. Both approaches are completed. The project has been delayed by numerous strikes.

CARPENTER DAM ON THE OUACHITA RIVER, ARK.

Hydro-Electric Power Projects

Fifteen Mile Falls Development—The first of two hydro-electric projects to be developed by the Connecticut River Development Co. on the Connecticut River at Fifteen Mile Falls, near St. Johnsbury, Vt., was started in August, 1928, and is scheduled for completion in October, 1930. Both projects involve combination earthfill and gravity concrete dams about 175 ft. high with a total development of 300,000 hp. On the lower project, now under construction, the 800-ft. concrete overflow section has been completed. The non-overflow concrete section, containing the power house, the retaining wall 165 ft. high between concrete and earth-fill sections, and the 275,000-cu.yd. earthfill are still under construction. Steelwork has been completed on the power house. Over 240,000 cu.yd. of concrete will be used in building the dam.

Safe Harbor Project, Susquehanna River—Preparatory work for a 231,000-hp. hydro-electric power development on the Susquehanna River 8 miles below Columbia, Pa., is under way and construction work in the river bed is expected to start in the spring. Work will be carried on from the east side of the river only, due to the inaccessibility of the west shore. The 3,625-ft. dam will create a head of 52.5 ft.

Saluda Dam—Approximately 9,500,000 of a total of 11,000,000 cu.yd. has been placed in the Saluda hydraulic-fill dam under construction by the Lexington Water Power Co. near Columbia, S. C. Fill is now being made from trestle El. 353. The crest will be at El. 372. The spillway structure and power house are under construction, and work has started on the steel surge tank. Impounding the reservoir commenced last September, and the lake is now at El. 304.22.

Little Tennessee River Developments—Construction of the Calderwood (Tenn.) hydro-electric project is about completed. This is the third development to be built by the Aluminum Company of America on the Little Tennessee River and its tributaries. Another dam and power house, to be built at Chilhowee, Tenn., just below Calderwood, has been delayed in getting started by the disposition of a line of the Southern Ry., which will be submerged by the proposed lake. Preliminary construction has started on the company's high head development to be built on Nantahala Creek, near Nantahala, N. C.

Furman Shoals Dam—Preliminary construction was begun late last fall on the Georgia Power Co.'s 60,000-hp. hydro-electric development at Furman Shoals, on the Oconee River, 5 miles north of Milledgeville, Ga. The dam will be 2,960 ft. long with a concrete gravity section in the center and earth-fills on the ends. The maximum height will be 93 ft. Over 425,000 cu.yd. of earth and 186,500 cu.yd. of concrete will be required for the project. To date more than 100 camp and organization buildings have been completed, and highway and railroad connections to the project have been made. Completion of the project ready for operation is scheduled for the summer of 1931.

Carpenter Hydro-Electric Development—The Carpenter hydro-electric development, under construction for the Arkansas Power & Light Co., is located on the Ouachita River 4 miles south of Hot Springs, Ark., immediately upstream from the company's Remmel project. The Carpenter development will consist of a concrete gravity dam of 115 ft. maximum height, having an over-all length of 1,164 ft. The power house will have a present installation of two 28,000-kw. generators operating under a rated head of 89 ft. Provision is made for installation of a possible future third unit. The reservoir formed by the dam will have an area of about 8,000 acres and an effective storage capacity of 95,000 acre-ft. within the limits of the drawdown. This development was authorized and construction was started in 1929. It is scheduled for operation in the fall of 1931.

Salt Springs Dam—Dumping 125,000 cu.yd. of rock a

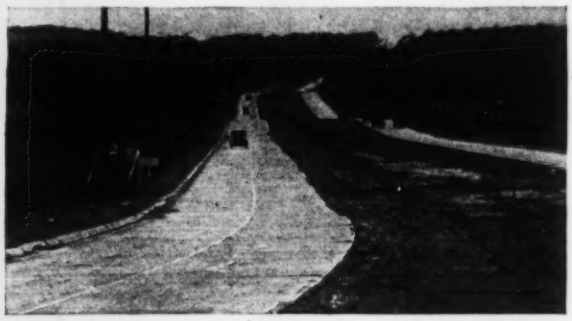
month into the Salt Springs rockfill dam, the Pacific Gas & Electric Co. has completed 50 per cent of this structure, which will form part of a hydro-electric project on the Mokelumne River in California. The derrick-placed rock section on the upstream face is well above outlet level and it is planned to pour enough of the reinforced-concrete facing slabs to permit some storage during the coming season for existing plants on the river. This record-breaking rockfill dam will be 328 ft. high with a crest length of 1,300 ft. It will contain approximately 3,000,000 cu.yd. of rock, including 220,000 cu.yd. in the derrick-placed portion on the upstream face, and will require 30,000 cu.yd. of reinforced concrete in the facing slab. Excavation work along the 18-mile conduit line, which starts immediately below the dam, has commenced. Plans call for completion of the dam, conduit and the new Tiger Creek power plant (60,000 kva.) in 1931.

Diablo Dam, Seattle Power Project—The Diablo dam is a constant angle arch nearly 400 ft. high being built in the Skagit River gorge, 100 miles northeast of Seattle, as part of that city's hydro-electric development. Contract was awarded in September, 1927, completion of the work being scheduled for September, 1929. The work is not yet finished and although the structure has been brought to full height for part of the crest length, some months will be required for completion. Keeping the water out of the gorge while placing foundations was difficult, but the principal causes of delay have been high water over the gravel beds and a serious accident to the incline over which materials are delivered to the concreting plant. Conforming to an unusual requirement in the specifications, the contractor successfully developed a scheme of placing concrete by means of conveyor belts, thereby avoiding the use of chutes. The work was shut down Dec. 5 by the first heavy snowfall of the winter.

British Columbia Hydro-Electric Projects—Construction work is under way on two projects in British Columbia that ultimately will make an additional 782,000 hp. available to the system of the British Columbia Electric Railway Co. The Ruskin project on Stave River will consist of a concrete gravity dam 184 ft. high with penstock tunnels direct to the power house adjoining the dam, where one 44,000-kva. unit will constitute the initial installation. Diversion works at the damsite have been finished and concrete is being poured; completion is scheduled for late in 1930. On the Bridge River project construction to date has been confined to work on a 13,200-ft. tunnel of 14 ft. 3 in. diameter to have a capacity of 2,100 sec.-ft. The initial installation on this development probably will be 60,000 kw. and will not be placed in operation until 1932. The development under way on these two projects calls for expenditures of more than $22,000,000 and constitutes one of the largest hydro-electric programs now in progress on the Pacific Coast.

Saguenay River Power Development—Construction of a 260,000-hp. hydro-electric plant at Chute-a-Caron, on the Saguenay River in Quebec, the first stage of a 1,000,000-hp. development, was begun in 1927. To date the greater part of the dam and the foundations for the power house have been completed. Closure of the dam will be made near the end of this year and it is hoped to have the plant in operation in 1931.

Beauharnois Hydro-Electric Project—Construction work on the Beauharnois Power Corporation's hydro-electric development on the St. Lawrence River in the Province of Quebec started Aug. 1, 1929, and was carried on until the end of December, when work was suspended on account of winter weather. The project will consist primarily of a canal 15 miles long and 3,000 ft. wide cutting across a bend of the river and connecting Lakes St. Francis and St. Louis, with the power house to be located at the edge of Lake St. Louis. The initial installation will consist of ten 50,000-hp. units operating under an 83-ft. head. Construction of the project will require three years' time and involves the removal of 25,000,000 cu.yd. of earth and 1,500,000 cu.yd. of rock. At present there has been nearly 600,000 cu.yd. of excavation removed; 15,000 ft. of dike, which will line the side of the main canal, has been completed; and 5 out of a total of 40 miles of construction railroad have been built.



BLUE MOUND HIGHWAY, MILWAUKEE COUNTY, WIS.

Water Supply Structures

New York City Water Tunnel—Considerable progress was made in 1929 in the construction of the 20-mile water tunnel of the Board of Water Supply of the city of New York. This tunnel, to be concrete lined throughout, extends in rock about 500 ft. below street level from Hill View reservoir at the city line in Yonkers into Brooklyn, passing under the East River at Rikers Island. Of the nineteen shafts having an aggregate depth of 10,265 ft., there had been excavated at the end of the year 7,161 ft., and 6,331 ft. of this amount had been lined with concrete. Nine of the shafts of the Long Island portion of the tunnel were sunk by compressed-air caissons through 100 ft. of water-bearing sand and sealed into rock before progressing further with excavation of the shafts without the use of air. Tunnel headings have been turned in three of the shafts and four others are nearly down to tunnel grade. Installation of headframes and tunnel plant is in progress at these shafts. The four contracts covering the construction of the tunnel were awarded to one contractor on Oct. 5, 1928, at a total estimated cost of $42,692,567. At the end of the year there had been estimated for payment on these contracts $5,291,846, or about 12½ per cent of the total, excluding miscellaneous work done by the city aggregating $391,000.

Hetch Hetchy Project—San Francisco went through a prolonged drought last fall which focused public attention on the 29 miles of tunnel on the Hetch Hetchy water project now being driven through the Coast Range Mountains. In addition to the Coast Range tunnels, 47.4 miles of steel pipe across the San Joaquin Valley will be needed to complete the aqueduct. The first of the valley pipe lines, however, can be built in a relatively short time; hence the tunnels constitute the limiting factor on delivery of the mountain water supply. The main storage reservoir on the project, which has been completed for some years, was full even in the very dry year just past. The mountain water is now expected in San Francisco in the fall of 1932. Up to the end of the year just closed the total advance in the several headings of the Coast Range tunnels had been 41,411 ft. Ten to twelve headings have been used at different times; fourteen is the maximum number considered economical under the topographical conditions that obtain. During the fall the city was successful in selling the $41,000,000 in bonds voted a year ago for the purchase of the distribution system and other Spring Valley Water Co. properties. With ample funds now in hand for the completion of the Hetch Hetchy project and having settled the Spring Valley purchase problem, the city now for the first time in its history can look forward definitely to operating its own water-supply system. Including the Spring Valley purchase, the bond issues for the completed system represent a total of $120,000,000.

Detroit Water Supply—Substantial progress has been made during the year on the construction of the additional water-supply system which will augment the city's present facilities. The 10-mile concrete tunnel connecting the new Springwells station with the Detroit River is very nearly completed and the contract for the last 2,300 ft. of 14-ft. diameter tunnel will be let early in 1930. Work on the 15½-ft. rock tunnel, linking up this last section with the new intake under construction in the Detroit River, has been under way for some months and tunnel excavation has proceeded for some 1,000 ft. The shaft located at the junction of the two tunnels has

been completed to the ground surface. Work has started on the construction of dikes to form a lagoon in which the intake structure will be located and on the construction of the substructure of the intake. At the Springwells station site, one 20,000,000-gal. unit of the filtered water reservoir is very nearly completed, and the concrete substructure for the filter plant is scheduled for completion early in the summer of 1930. The foundations for the pumping stations, power house and generator plant are under construction. These buildings will be ready for the superstructures in the summer of 1930. The expansion of the distribution system by 15 miles of steel water main from 48 in. to 72 in. in diameter has been carried well along. Completion of the entire project is expected about 1932.

Wanaque Aqueduct—Completion in the very near future is expected of the Wanaque project of the North Jersey District Water Supply Commission. Construction has progressed to the point where it would be possible now to turn water into the entire 20½-mile length of aqueduct. The reinforcement of the Wanaque and the Great Notch tunnels, construction of the approaches for the latter, and the laying of the steel pipe for the aqueduct proper have all been completed. After the line has been formally tested and sterilized, it will be ready to deliver water, probably in the early spring. Contracts have been let for the construction and installation of the headworks and equipment at Wanaque, and it is expected that the contract for the construction of the balancing reservoir to be located near the lower portal of the Great Notch tunnel will be awarded in February.

Wachusett-Coldbrook Tunnel, Boston—Only 1¼ miles of the 15-mile Wachusett-Coldbrook tunnel being driven for Boston's water supply remain to be holed through. Concrete lining of the bore will be commenced early this spring, and it is expected that most of it will be finished this year. Works for diverting Ware River into the tunnel are about half completed and probably will be finished this year.

Cobble Mountain Dam, Springfield, Mass.—Sluicing has commenced on the Cobble Mountain hydraulic-fill dam being built on Little River above Westfield, Mass., for Springfield's water supply. The fill will contain nearly 2,000,000 cu.yd. of material and will rise 245 ft. above the streambed, a record height for this type of dam. Excavation has been completed on the outlet tunnel, 7,100 ft. long, which will also be a pressure tunnel for a power plant to be located at the headwaters of the present supply reservoir in Little River Gorge. Work is under way on the tunnel lining and the power house construction.

Large Steel Conduit, Philadelphia—Four out of seven miles of steel force main have been completed for the Philadelphia water-works. The work done includes 14,000 ft. of 93-in. pipe out of a total of 19,900, and 7,000 ft. of 72-in. out of 14,400 ft. The force main runs from the Torresdale pumping station on the Delaware River to a distribution terminal.

Railway Terminals and Improvements

Cleveland Union Terminal—Cleveland's new Union Terminal is now in partial operation. With the entrance on Dec. 1 of trains operated by the New York Central, the Big Four and the Nickel Plate railroads, the terminal project entered the final stages of completion. Trains are now being operated into the station under steam, but with completion all services into the station and over its approaches will be electrified. There will be in all about 17 miles of electrification, of the overhead catenary type, about half of which has been completed. The necessary bridges and retaining walls along both east and west approaches have been completed. Some grading and track laying remains to be done over the east approach between East 40th St. and the terminal. Of the building developments of the terminal area the 52-story Terminal Tower, the eighteen-story Medical Arts Building and the eighteen-story Builders Exchange and Garage Building have been completed and the steel has been erected for another building of the same size, the Midland Bank Building.

West Side Track Elevation, New York City—Plans for the removal of the tracks of the New York Central R.R. from the surface of the streets on the west side of Manhattan Island, New York, received final approval in December and preliminary work has been started. Construction of 5 route miles of depressed or elevated double track, largely upon a newly acquired private right-of-way, double-deck yards and electrification of the line is involved. The cost is estimated at $138,700,000.

Pennsylvania Terminal, Philadelphia—Reconstruction of the Pennsylvania R.R. terminal in Philadelphia and West Philadelphia involves placing the main passenger station in West Philadelphia and the replacement of Broad St. station in Philadelphia by an underground station for suburban trains. The work was begun in 1925. To date the new

PHILADELPHIA & READING'S NEW BROAD STREET STATION, PHILADELPHIA

bridge over the Schuylkill River and the subway approach to the new Philadelphia station are well along toward completion and rearrangement of the West Philadelphia yard in preparation for the new terminal is under way.

Cincinnati Union Station—After a long period of promotion and planning for a new union passenger station at Cincinnati, Ohio, definite plans were approved by the city and the terminal company in July, 1929, and a contract for $2,774,870 for grading the site was awarded in August. The location for the terminal, which will include equipment facilities, is a 300-acre site on the west side of the city. Considerable work on new approaches will be required to bring some of the railroads into the station. Extensive revisions of existing freight terminal facilities are also necessary. The passenger station will be of the through-track type, with tracks and platforms on the lower level and the main station facilities and concourse at an elevation 30 ft. above the existing street level. It will be used by all the seven railroads entering the city, accommodation being provided for about 150 inbound and 150 outbound trains daily by fourteen station tracks and seven platforms. Provision is made for 22 tracks and eleven platforms in all. As the greater part of the 300-acre site is subject to flooding when the Ohio River reaches a flood stage of 50 ft., the entire area will be built up to an elevation higher than the maximum flood stage of 71 ft. This will require about 6,000,000 cu.yd. of fill. The total cost is estimated at $41,000,000, and it is expected to have the station ready for service in December, 1933. The work planned for 1930 includes team-track yards and freight yard work estimated at $4,330,000; railway relocations, $1,650,600; street grade revisions, $590,000 and the Western Hills highway viaduct across the site, $3,500,000. The contract for this viaduct will be let by the city.

Flood Control and Navigation

Conklingville Dam—Hydraulic sluicing has been completed on the earth dam being built by the Board of Hudson River Regulating District on the Sacandaga River at Conklingville, N. Y., and the rolled-fill topping will be finished as soon as weather permits a resumption of operations. The dam will contain 670,000 cu.yd. of earthfill and 120,000 cu.yd. of rockfill. Construction of the power house is under way. The reservoir formed by the dam will cover an area of 42.3 square miles and will have a capacity of approximately 30 billion cubic feet.

San Gabriel Dam—Faulted and shattered foundation rock at the San Gabriel dam site, revealed only after extensive

excavation work had been done, resulted in the State of California refusing the Los Angeles County Flood-Control District permission to build the proposed 500-ft. concrete dam. This action resulted in a cancellation of the construction contract by the district, although exploration work by means of shafts and tunnels is being continued at the site to determine the possibility of a different type of structure. The consulting board that advised the state engineer suggested that a rockfill or earth dam of conservative design could be built with safety at this location. These possibilities are now under consideration by the district with a view to securing some storage at the location where $3,000,000 already has been spent. It is thought that a rockfill or earth dam supplemented by smaller dams upstream might provide a sufficient total storage. Because the bond issue was voted for the building of the high concrete dam, future work on this part of the flood-control program, either in the form of a lower dam at the same site or dams at other locations, awaits decision of the county board as to making the bond money available for these other uses.

Owyhee Reclamation Dam — During the year work progressed satisfactorily on the 522-ft. Owyhee dam, being built in eastern Oregon for the U. S. Bureau of Reclamation. The 22x1,005-ft. diversion tunnel was lined with concrete, as was the spillway shaft which makes the tunnel a part of the finished project. On Dec. 1, the 1,300-ft. cableway across the gorge was put into service and was used to expedite removal of material from the lower parts of the excavation. By the end of the year excavation in the canyon bottom was nearly completed, the foundation having been uncovered for most of the prescribed area. Work on the dam as a whole was reported 25 per cent complete early in December. The 4-cu.yd. mixers built expressly for this job were en route to the dam, the 8-cu.yd. cylindrical buckets had already arrived, and concrete pouring was expected to commence before the coming summer.

Dallas Flood Protection—To restrain the Trinity River within a leveed channel for about 7 miles and thus permit the reclamation of a large portion of its valley for industrial development at Dallas, Tex., the city, county and an old levee district are co-operating in a project now under construction. These levees will form a floodway 2,000 to 3,000 ft. in width, with a dry-weather or low-water channel in the middle. Four pumping plants equipped with screw pumps will handle storm runoff in the reclaimed area at flood periods when the culverts through the levees are closed, the borrowpits in this area being utilized for water storage in order to reduce the pumping capacity. Part of the old river channel through the city will be filled by pumping sand into it. This project will cost about $13,000,000, approximately half of which will be paid by the city and county, organized as a levee district, and the remainder by the railways and public utility companies in conforming to the improvements.

Welland Ship Canal—The new Welland Ship Canal being built by the Canadian government to replace the present canal between Lake Erie and Lake Ontario is rapidly approaching completion. Work last year was confined to the portion of the canal between Thorold and Port Colborne. During this winter provisions will be made for turning traffic from the old canal into the new canal at lock 3 for passage to Lake Ontario. This will eliminate seven locks-ages. The entire canal will be ready for operation by midsummer.

Other Large Projects

Sanitary District of Chicago—Owing to the failure of a bond issue in December, 1928, the construction activities of the Sanitary District of Chicago were practically suspended during the major portion of 1929. The Illinois Legislature, however, granted relief on July 1, 1929, by authorizing the issue of $27,000,000 of bonds for work on the government program. Bonds amounting to $10,150,000 were sold in September and work was resumed in October. At the West Side sewage-works, preparations are being made for putting into operation in February one of the three batteries of Imhoff tanks, together with the main pumping station and structures for preliminary treatment. The second battery of tanks should be completed by July 1. The necessary sludge drying beds and most of the appurtenances will be completed sufficiently to permit sludge drying during the summer. This plant is designed for an initial population of 1,850,000, besides providing for the digestion and disposal of the waste sludge from the North Side works. Construction is proceeding on the intercepting sewers and additional contracts are to be let this year. The estimated cost of the treatment plant for sedimentation only is about $30,000,000, and of the interceptors $27,000,000.

The North Side sewage works have been in partial operation during 1929, awaiting the completion of the North Branch pumping station, which will bring in the remaining one-fourth of the population now tributary. It is hoped to have the station in service and operate the North Side works at full capacity by the early summer. The total cost of the treatment works proper, with the sludge force main to the West Side works, will approximate $19,500,000, and of the interceptors and the North Branch pumping station, $14,500,000.

World's Largest Building—The Merchandise Mart, Chicago, which was practically completed by the end of 1929, is said to be the largest commercial building in the world. It is an 18- and 25-story warehouse surmounting the two-story city freight terminal of the Chicago & Northwestern Ry. and is an air-rights structure whose property begins at 23 ft. above city datum. On the upper street, or viaduct, level is the railway's team floor with driveways and platforms. On the lower street level are nine stub and through tracks and three platforms, with elevators to the upper floors and to the tunnels of the Chicago narrow-gage freight-handling electric railway system. In plan the warehouse building has two sides 724 and 580 ft. long and is 324 ft. wide, having about 53,000,000 cu.ft. and giving 4,000,000 sq.ft. of rentable floor area. It is of steel frame construction, on concrete foundation piers and has concrete floors and roof. Placing concrete by means of a series of 44 fixed and portable conveyors serving four mixers was a feature of the construction work, this equipment placing a total of about 250 cu.yd. per day.

Detroit-Canada Vehicular Tunnel—According to present plans, the vehicular tunnel connecting the business district of Detroit with Windsor, Canada, will be opened to traffic Nov. 1, 1930, about two months ahead of schedule. The subaqueous portion, 2,454 ft. long, consists of nine sunk-in-place segments, eight of which are completed at the present time. These segments are of structural steel, lined and incased with concrete after being floated. The Detroit approach is practically completed, as is the subway approach on the Canadian side. The tunnel section approach in Windsor is about 50 per cent complete. The superstructure of the ventilating building in Detroit is up and the Windsor ventilating building has been started. Ventilating machinery is manufactured and ready to install. The tunnel is a toll project and is owned by the Detroit & Canada Tunnel Co.

New York Subways—Contracts totaling $112,351,998 were awarded in 1929 by the New York Board of Transportation for rapid transit construction mostly on the city's independent system covering nearly 50 miles of line. During the year structural work progressed on more than 40 major sections of new subway. In Manhattan, the Eighth Ave.-Sixth Ave. extension line is practically completed. The 53rd St. cross-town line and tubes under East River are also about finished. Downtown, the Fulton St. tubes under East River are about ready for track, and the Houston-Essex line, involving also the widening of these streets, is about 10 per cent completed. New routes in Brooklyn vary from 10 to 80 per cent completed. Several contracts on lines in this borough are yet to be let. In Queensboro the Jackson Ave.-Broadway line is under construction from East River to 55th Ave. One contract has been awarded and several more are yet to be let on the Queens Boulevard extension of this route. Last year announcement was made by the Board of Transportation of plans for 100 miles of additional lines to be built at a construction cost of approximately $438,000,000, which will reach from lower Manhattan to the Bronx, and to outlying sections of Queens and Brooklyn. Hearings on this proposed system are now being held by the board.

Facts and Figures of Construction

Slight Drop in Construction Activity During 1929 Likely to Be Made Up in 1930, With a Total Program of Ten Billions in Prospect—Public Works and Utilities Budgets Are Ample, Costs Continue Stable, and Financing Is Becoming Easier—Bond Sales on the Increase

FOR nine years past, each year has set a new high record of construction activity. Thus 1927 exceeded 1926, and 1928 went beyond 1927. But in 1929 this precedent failed, for with its contract total just over $9,130,000,000 the year fell back a slight amount below the 1927 figure and fully 9 per cent below 1928. It ranks as the third largest year of construction in the history of the United States.

Statistics of construction are not complete, but total volume can be appraised by adding to available figures the annual appropriations announced by the utilities and by public officials. The fullest statistics over a long period are those for engineering construction and residential building. In the last ten years these have aggregated 24 and 21 billion dollars, respectively, and account for about two-thirds of all construction. Using these data as a basis, total annual construction for the last twenty years is estimated as follows:

	Value of Total Construction	Cost Index Number (1913 Base)	Comparative Volume of Construction
1910	$1,490,000,000	96.33	99
1911	1,410,000,000	93.43	97
1912	1,560,000,000	90.70	110
1913	1,560,000,000	100.00	100
1914	1,410,000,000	88.56	102
1915	1,600,000,000	92.58	111
1916	2,420,000,000	129.58	120
1917	2,340,000,000	181.24	83
1918	2,780,000,000	189.20	94
1919	3,540,000,000	198.42	114
1920	3,380,000,000	251.28	86
1921	3,470,000,000	201.81	110
1922	4,900,000,000	174.45	180
1923	5,870,000,000	214.07	175
1924	6,230,000,000	215.36	186
1925	8,400,000,000	206.68	260
1926	8,700,000,000	208.03	268
1927	9,160,000,000	206.24	284
1928	10,000,000,000	206.78	310
1929	9,130,000,000	207.02	280

Six times as much money is being spent for new structures than was spent twenty years ago; the physical volume of work accomplished is only three times as great. It will also be seen from the table that in the period of 1916 to 1921 there was practically no increase in physical volume, although expenditures for construction rose considerably. Since 1922, however, the increase in volume of work has been phenomenal, due first to a housing shortage developed during the war and made up in the years 1922 to 1924, and second to the speeding up and expansion of general business. The figures from 1925 to date indicate a condition of stabilization at a volume level more than double that of former years.

1929 Activity.

The decrease in 1929 resulted from a severe decline in residential building. The drop is shown in the accompanying diagrams, and is almost exactly equal in both amount and slope to the rise in 1925. The decline totaled 31 per cent.

Engineering construction meanwhile continued to rise steadily from 1924 on, in tune with the pace of business. It maintained record levels throughout the first three quarters of 1929. Even though October contracts dropped unseasonably and November and December registered further drastic decreases, the year attained a total 10 per cent greater than 1928 engineering construction.

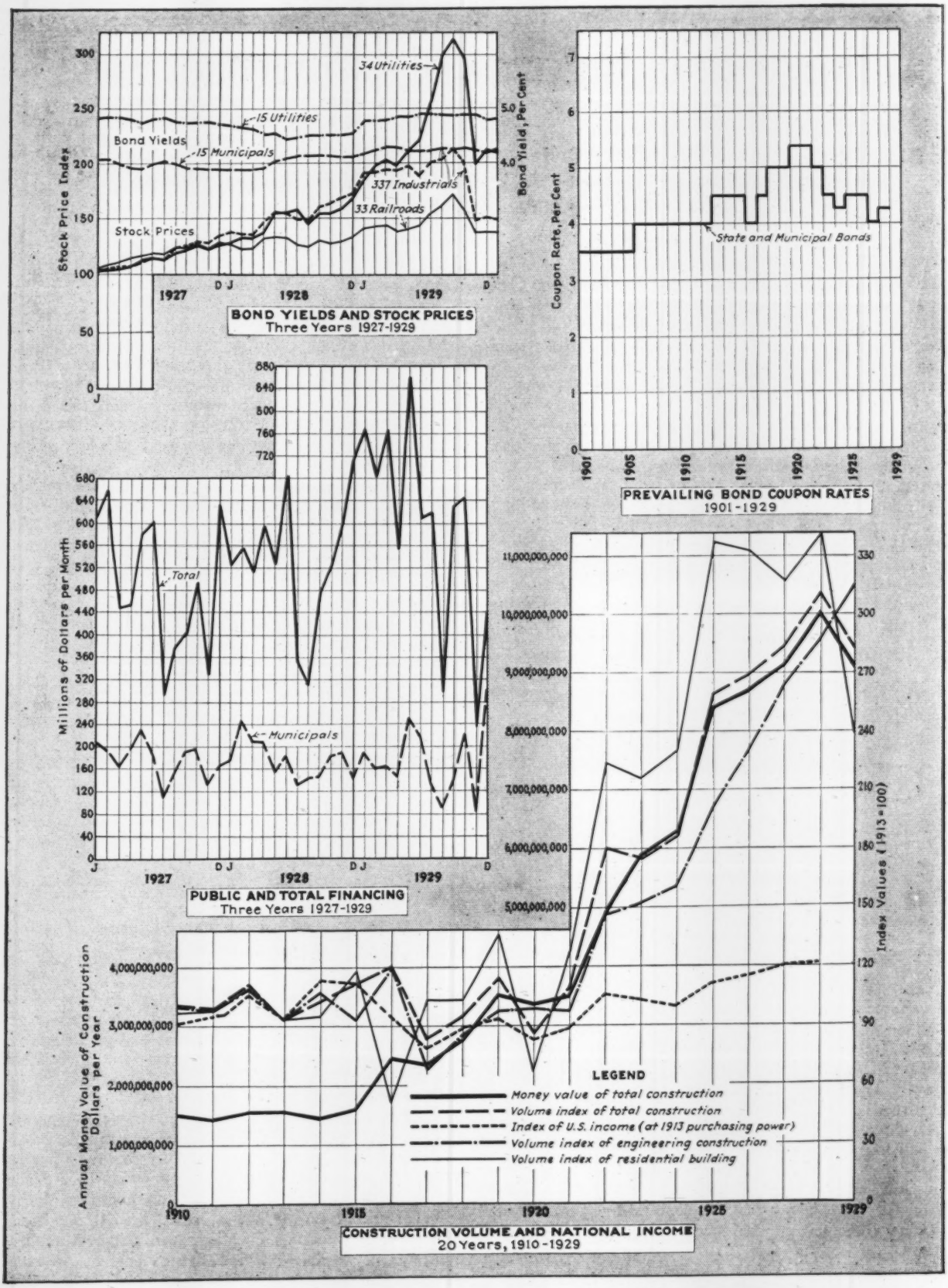
Construction is so closely dependent on the money markets that the course of stock and bond activities is closely related to the above-mentioned facts. The curves of prices of representative stock groups shown on the diagrams picture the speculative inflation and subsequent collapse. Bonds had a poor market during the inflation, but after it was ended the bond market quickly improved—money turned from stocks to fixed investment.

New security issues for the year (exclusive of refunding, foreign and non-productive) totaled $7,448,000,000, a gain of 14 per cent over 1928. Investment trusts and holding companies issued paper with a face value of $2,225,000,000, an increase of 170 per cent. The present trend is strongly toward bonds, $300,000,000 worth having been issued in a single week of January, 1930. The previous month, December, brought out 297 millions of dollars of state and municipal bonds, compared with 148, 109 and 111 in December of the three preceding years. Thus the outlook for that large element of construction which uses the proceeds of bond issues is promising.

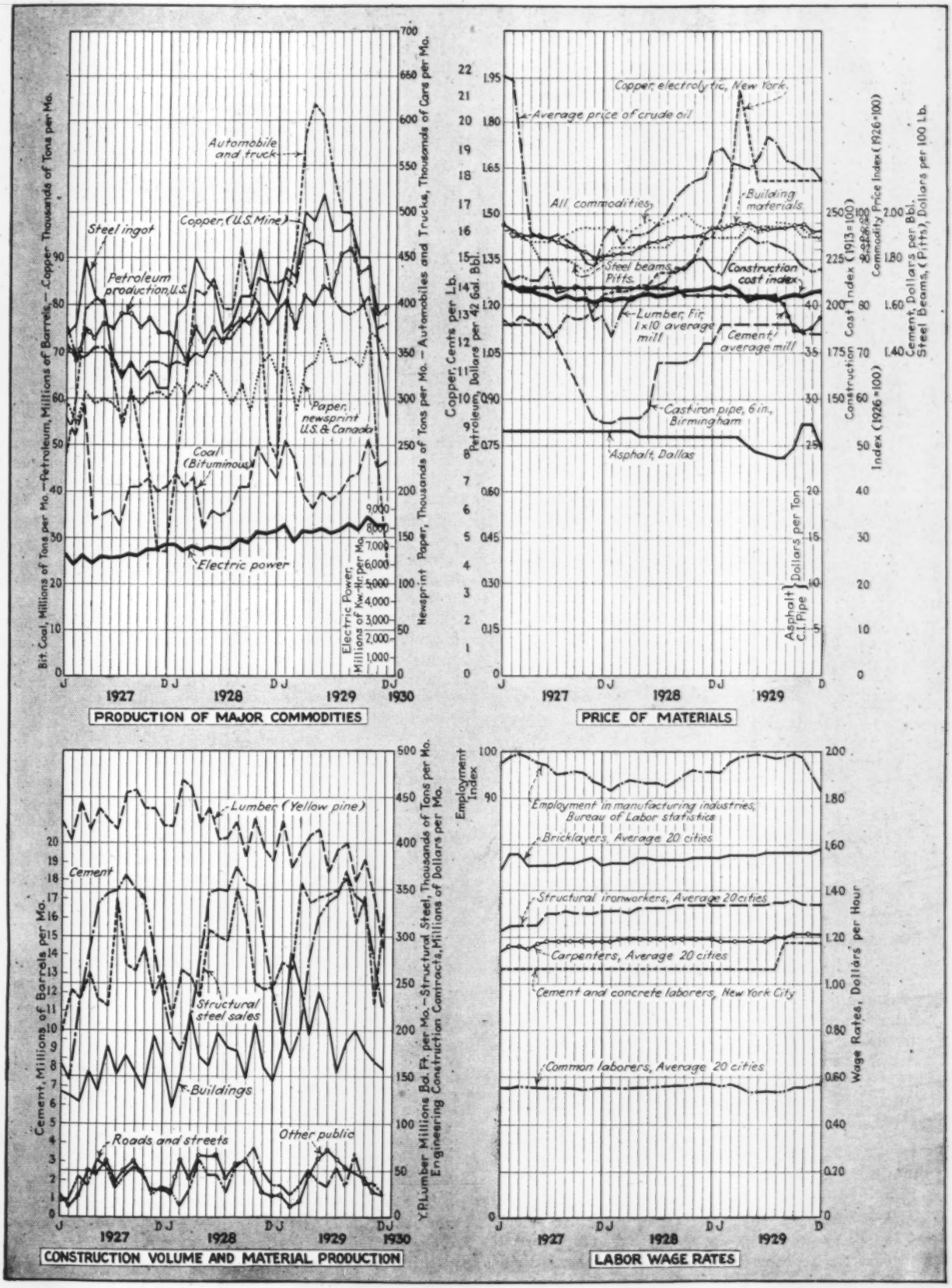
Programs of Construction in 1930

Figures presented at the Washington conferences in November and December by leaders of various fields of business show heavy programs of utility construction. The railroad budget is $1,050,000,000, an increase of 10 per cent over 1929. The central station budget is $913,575,000, an increase of 5 per cent over 1929 expenditures; this industry has a steady growth of nearly 10 per cent per year.

A summary of budgets shown in the accompanying table indicates that this year's total construction will reach 10 billion dollars, as it did in the record year 1928. In this compilation a deduction has been made for machinery and similar production equipment, partly from data and partly by estimate, though operating equipment of buildings (heating, ventilating, plumbing, lighting and elevators) is included as part of the construction expenditure. While the central stations are planning to spend $197,000,000 for steam plants only about 22 per cent of this appropriation is for structures. Of hydroelectric expenditures, 60 per cent is rated as



GROWTH OF CONSTRUCTION AND COURSE OF FINANCING

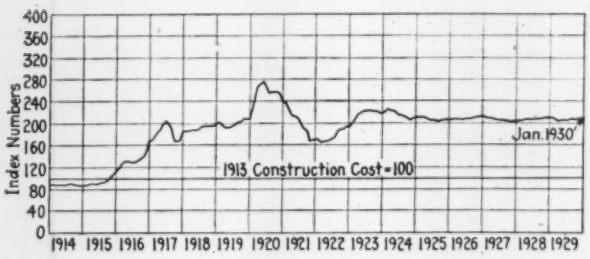

PRODUCTION OF MAJOR COMMODITIES
Bit. Coal, Millions of Tons per Mo. — Petroleum, Millions of Barrels. — Copper Thousands of Tons per Mo.
Newsprint Paper, Thousands of Tons per Mo. — Automobiles and Trucks, Thousands of Cars per Mo.
Electric Power, Millions of Kw.-Hr. per Mo.
Steel ingot
Copper, (U.S. Mine)
Automobile and truck
Petroleum production, U.S.
Paper, newsprint U.S. & Canada
Coal (Bituminous)
Electric power
1927
1928
1929
1930
PRICE OF MATERIALS
Copper, Cents per Lb.
Petroleum, Dollars per 42 Gal. Bbl.
Asphalt, C.I. Pipe, Dollars per Ton
Construction Cost Index (1913=100)
Commodity Price Index (1926=100)
Cement, Dollars per Bbl. Steel Beams, (Pitts.), Dollars per 100 Lb.
Copper, electrolytic, New York
Average price of crude oil
All commodities
Building materials
Steel beams, Pitts.
Construction cost index
Lumber, Fir, 1 x 10 average mill
Cement, average mill
Cast iron pipe, 6 in., Birmingham
Asphalt, Dallas
CONSTRUCTION VOLUME AND MATERIAL PRODUCTION
Cement, Millions of Barrels per Mo.
Y. P. Lumber Millions Bd. Ft. per Mo. — Structural Steel, Thousands of Tons per Mo.
Engineering Construction Contracts, Millions of Dollars per Mo.
Lumber (Yellow pine)
Cement
Structural steel sales
Buildings
Roads and streets
Other public
LABOR WAGE RATES
Employment Index
Wage Rates, Dollars per Hour
Employment in manufacturing industries, Bureau of Labor statistics
Bricklayers, Average 20 cities
Structural ironworkers, Average 20 cities
Carpenters, Average 20 cities
Cement and concrete laborers, New York City
Common laborers, Average 20 cities

TREND OF CONSTRUCTION VOLUME AND PRICE, 1927-1929

construction; transmission ($179,000,000), 100 per cent construction; distribution ($379,000,000), 85 per cent construction.

The total construction program is divided fairly equally between public works and utilities and private work, the latter chiefly buildings. Public work forms the certain element in the list. Of the 3 billions represented by this item about 1 billion is for municipal and $271,000,000 for federal work.

In round figures, then, the program now in sight calls for an increase of 11 per cent over last year's construction. The prospect is for a construction year equaling 1928 or even surpassing it by a slight margin.



CONSTRUCTION COST INDEX

January has not yet shown definite evidence of recovery in contract volume (60 per cent under 1929). This is hardly the season to look for high figures, however. March will be the significant month. Since the war, or since 1921, this month has always recorded a strong seasonal increase in contracts awarded. During the last nine years the March increase over February has been 63 per cent, 126, 26, 12, 11, 28, 21, 41 and 1 per cent. Continuation of the present low level of contract awards during February will not be surprising, but a heavy increase in March will be substantial proof of recovery.

Construction Costs Continue Stable

A glance at the curve of *Engineering News-Record's* construction cost index shows the persistent stability of this important factor. Since 1925 fluctuations have been negligible. The average change from 1926 was +0.116. The present index is only 2 per cent above a year ago. The outlook this year, based on five years' performance, on present market conditions, and on estimated demand, is for continued stability.

Materials Prices—The curves of prices of building materials outline the trend since 1927. The general condition was one of even price levels in 1929. Commodity prices departed from the building trend in July, 1927, but since September, 1928, the two curves agree closely. Probably the outstanding change of the year was the late-summer drop in cement prices, since recovered.

Lumber, Brick and Steel

Lumber manufacturers have maintained a policy of restricting output to close balance with consumption, as noted a year ago. The result has been firm prices. Steel shapes are the same as a year ago, though from May to September they were five cents higher. Brick business is well below that of a year ago and awaits a revival of residence construction. In the New York district production has stopped and, as elsewhere, shipments and stocks are small. Average delivered prices are: $14.63, compared with $15.13 a year ago. Increased demand is expected to raise prices. No important price changes of steel or of other materials are to be expected until construction volume rises strongly.

Unemployment

In keeping with the low volume level of all construction, employment in the building trades is the lowest in three years. This contrasts with the situation earlier in the year, when the five-day week was strongly urged and jurisdictional dispute was common. The outlook is for a continuation of 1929 wage schedules. Here, as with materials, advances must wait on volume.

Industrial unemployment is also increasing. The automotive and aviation industries are hardest hit. A favorable factor is that elsewhere, except in radio and luxuries, stocks are small.

Financing

Construction volume, the pivot of the whole construction situation and to a very considerable extent of the entire business and industrial situation, is strongly affected by the attitude of finance. The drop in residential building was due in large part to excessive credit costs. Added to these were burdensome bonus and discount charges. Lower interest rates (now 4¾ compared with 6 to 6.13 in May-September) should tend to encourage building in this class and in the commercial field. In the latter class, however, construction has been heavy in the last few years, and surplus space exists in many districts.

Mortgage money remains scarce, owing to reduction of savings and building and loan accounts for stock speculation. It may well be that when these funds are again available the building program will be larger than had there been no residential slump with accompanying development of need.

Industrial building, except by new corporations, is less dependent on outside financing. Expansion is usually in step with earnings, part of which are set aside for the purpose. The amount of this building, therefore, will depend on general purchasing power or consumption. No boom is expected here.

Public Bonds—Public works construction in 1929 was 5 per cent under 1928. Although bond financing slightly exceeded that of the previous year, it was considerably smaller than it would have been with a favorable market, now apparently present. Heavy sales are expected during the next few months. But bonds constitute only a part of public works financing; of roads, which amount to at least half of all public works, only 17 per cent is built with the proceeds of bond sales. It is this division of construction that forms the strongest part of the 10 billion dollar program.

ESTIMATED CONSTRUCTION BUDGET FOR 1930

Class A railroads	$660,000,000
Central stations	
Steam (22.72% of budget)	45,000,000
Hydro-electric (60% of budget)	57,000,000
Transmission (100% of budget)	179,000,000
Distribution (85% of budget)	322,000,000
Other utilities (66% of budget)	850,000,000
Public utilities	$2,113,000,000
Public works for states and municipalities	3,053,742,900
Federal construction	271,257,100
Public works	$3,324,999,000
Private buildings	4,496,896,000
Other private construction	200,000,000
Private construction	$4,696,896,000
Total construction	10,134,895,000

News of the Week

Two States to Confer on Second Hudson River Traffic Tunnel

Commissions appointed by the states of New York and New Jersey will meet Feb. 14 to discuss the proposed New York - Weehawken vehicular tunnel under the Hudson River at 38th St., New York (*Engineering News-Record*, Jan. 16, 1930, p. 124), and to determine whether supervision of this project should be vested in the Port of New York Authority or the New York and New Jersey commissions at present in charge of the Holland tunnel.

Illinois Gas Tax Suit Dropped

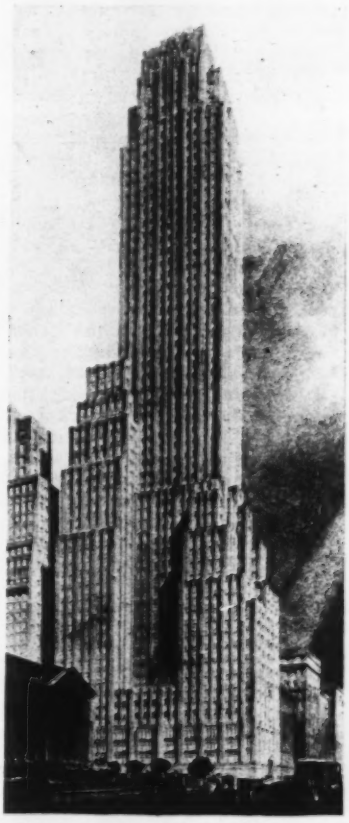
After the Illinois 3c. gasoline tax law went into effect last August more than a hundred suits were filed against its validity by oil and truck companies. Most of the suits were withdrawn, but a few went to trial in the lower courts. Recently one of them reached the State Supreme Court on appeal. This appeal was withdrawn Jan. 24, clearing the way for the state's $25,000,000 1930 road-building program. Highway funds in Illinois come from license fees as well as the 3c. gas tax, of which 1c. goes to the counties pro rata in the way of direct payment to contractors after approved work has been completed.

Pasadena Starts Work on Dam in San Gabriel Valley

The city of Pasadena, Calif., will proceed at once with the construction of its projected $10,000,000 Pine Canyon dam and conduit in the San Gabriel Canyon despite threatened court action, according to S. B. Morris, chief engineer, and James H. Howard, special water counsel. This statement was forthcoming in reply to the formal protest against the project which had been submitted by the San Gabriel Valley Protective Association following the action of the city in starting preliminary work in the canyon for its dam and conduit. The association is composed of riparian owners of the prescriptive rights and, by appropriation, owners of water in the canyon, and they protest against any and all work in the canyon which will impede or interfere with the free flow of the river.

The city maintains that no water will be impounded except during periods when unregulated flow from the canyon would reach the sea, and that sufficient water will be released each year to satisfy existing rights. A permit for the proposed construction was issued July 9, 1929, by the division of water rights of the California Department of Public Works.

NEW 58-STORY BUILDING FOR NEW YORK CITY



Architect's drawing of the 697½-ft. building now being erected at the corner of Fifth Ave. and 42nd St., New York City, one of the busiest corners in the world. Shreve, Lamb & Harman are the architects and Charles D. Wills, Inc., the builder. This structure will have a total rentable area of approximately 500,000 sq.ft.

Transfer Hydraulic Laboratory From Memphis to Vicksburg

The hydraulic laboratory of the U. S. Engineer Corps proposed for study of Mississippi River conditions has been transferred from Memphis, as noted in *Engineering News-Record* p. 998, Dec. 26, 1929, to Vicksburg. Thus this activity of a general nature is located at the same place as the new headquarters of the Mississippi River Commission recently removed from St. Louis. Lieut. H. D. Vogel, in charge of the laboratory, has altered the plans to fit the new location and is pushing the work so as to make the facilities of the laboratory available for the coming season of high water.

Railway Survey Included in Work of Army Engineers in Nicaragua

The Secretary of War has accepted an arrangement with the government of Nicaragua whereby the battalion of the U. S. Engineers now engaged in making a survey of a route for a canal through Nicaragua will, in addition to this work, survey a rail route from Lake Nicaragua to the Atlantic coast, via the San Juan River valley. This survey, when completed, will be made available to the government of Nicaragua. In return the government of Nicaragua will, while the Engineers are engaged in their present work, furnish free transportation of man and supplies of the battalion on the railroad and lake steamers belonging to the Pacific Railroad of Nicaragua.

Cleveland Names New City Manager

Daniel E. Morgan, lawyer and former state senator, was chosen on Jan. 27 to be city manager of Cleveland, Ohio, succeeding William R. Hopkins, who was removed from office Jan. 12.

Contractors Settle Claim for San Gabriel Suspension

A settlement has been reached between the Los Angeles County board of supervisors and Fisher, Ross, MacDonald & Kahn, the contractors who had been awarded the contract for the construction of the San Gabriel dam, whereby the contractors will receive additional compensation of $830,765.90. The contractors already have been paid $1,831,312.80 for excavation work at the Forks site on the San Gabriel River which Edward Hyatt, state engineer of California, condemned as unsafe for the 500-ft. dam which the county planned to erect for its flood-control project. The amount of settlement, $830,765.90, covers the following items:

Due contractors for yardage excavated	$244,463.70
Due contractors on account of 10 per cent held back	203,479.20
Force account, tunnel work	8,044.00
Stand-by charge	282,000.00
Equipment to be bought by county	92,779.00

The last items includes contractors' supplies on the damsite which the county expects to use in other flood-control projects in the San Gabriel Canyon.

The settlement ends negotiations which have been under way for some time between representatives of the county board of supervisors and the contractors and effects a compromise

of the contractors' original claim of $4,190,459.20. Final payments are expected to be made to the contractors next week, and when that has been accomplished there will remain about $20,419,000 of the $25,000,000 bond issue voted for a flood-control project in the San Gabriel Valley. Plans for the expenditure of this money for flood-control measures in the canyon now are being discussed by the county board of supervisors.

Brief News

NEGOTIATIONS between the states bordering the Colorado River are still in progress. The meeting adjourned in Reno and reconvened in Phoenix Feb. 5. Among other things it is expected that some decision will be reached as to whether Arizona will join the agreement or go to the courts to determine her rights.

A WATER TUNNEL traversing the city of Toronto from east to west will be constructed by the Rayner Construction Co., of that city, at a contract price of $3,823,218. It will traverse rock the entire distance and will be lined with concrete.

ARGUMENTS ON THE CHICAGO DIVERSION CASE will be heard March 12 by the U. S. Supreme Court, according to an order issued Jan. 27 advancing the date, which had previously been set at Feb. 24. Abstracts of record must be filed by Feb. 20.

WORK WILL START in a short time on the construction of a concrete seawall, approximately 5½ miles long, along Lake Pontchartrain at the west end of New Orleans. The contract has been awarded to the Orleans Dredging Company of that city on a bid of $1,956,208.

LOS ANGELES has initiated court action to condemn property of the Southern California Edison Co. in territory recently annexed to the city.

THE CONTRACT for the structural steel to be used in the construction of the Empire State Building in New York City has been awarded to Post & McCord by Starrett Brothers, Inc., general contractor of the new building. Approximately 53,000 tons of fabricated steel is included in the contract.

THE INTERSTATE COMMERCE COMMISSION has dismissed proposals initiated by the Public Utilities Commission of Idaho, the Lewiston (Idaho) Commercial Club and the Clarkston (Wash.) Chamber of Commerce for requiring the Northern Pacific, Oregon-Washington Railroad & Navigation Company and the Camas Prairie Railway to extend their terminal facilities from Lewiston to Clarkston by bridging the Snake River and to build an extension of 126 miles from Clarkston to Homestead, Oregon. The commission held that there is no public need for the proposed extensions.

The Business Outlook

The market is clearly graining ground against the steady liquidation of bank security loans and investments, and the banks are thus getting more elbow room in which to handle increasing spring business credit needs. But for all except the most liquid loans, money is still tight and the need for lower rediscount rates continues. It is doubtful whether present signs of business recovery can be fully realized or long sustained without more Reserve Bank aid than has so far been forthcoming. Steady reduction of member bank indebtedness and falling bank rates abroad bring this nearer.

Steel-mill activity made a further surprisingly sharp gain of over 5 per cent for the latest week, the average for the industry rising from 69 per cent of capacity to 74 per cent, as compared with 84 per cent a year ago. Under the stimulus chiefly of increasing automobile production, official government figures show a marked and general increase of employment in the second week of January.

—The Business Week, Feb. 5.

Official Nominations Announced by A.W.W.A.

Official nominees for the offices to be filled at the St. Louis convention of the American Water Works Association, to be held during the week of June 2, have been announced by the governing board. George H. Fenkell, superintendent and general manager of the board of water commissioners, Detroit, Mich., has been nominated as president and William W. Brush, chief engineer, department of water supply, gas and electricity, New York City, for treasurer.

Texas Railway Construction Conditionally Approved

Construction by the Gulf & West Texas Railway of a line from Fredericksburg, Gillespie County, to Brady, McCulloch County, 69 miles, and of a line from Eden, Concho County, to San Angelo, 44 miles, has been approved by the Interstate Commerce Commission upon the condition that construction of the line from Eden to San Angelo shall not be undertaken until the railroad obtains trackage rights over the line of the Gulf, Colorado & Santa Fe between Brady and Eden or is later authorized by the commission to construct a line of its own between the two points. The new construction would form part of a new direct route between southeast and northwest Texas. Cost of construction is estimated at $5,227,665.

WASHINGTON NOTES

By PAUL WOOTON
Washington Correspondent

Senate Approves Increase in Federal Aid—Congress Asked to Clarify Railway Valuation

WITHOUT a roll call and almost without debate the Senate last week passed the new federal-aid road bill, adding an amendment increasing to $25,000 per mile the amount of federal funds that may be expended. There may be objection to this in the House, where there has been some tendency to cling to the $15,000 maximum. It is believed, however, that this difference will be ironed out promptly in conference.

Potomac Parkway Approved

With only 24 votes cast against it, the Cramton bill, providing for the $23,000,000 George Washington memorial parkway, was passed Jan. 30. The bill provides for the purchase of a narrow strip of land on each side of the Potomac from Chain Bridge, at the District of Columbia line, to a point just above Great Falls. Similar purchases are authorized on several creeks tributary to the Potomac.

The bill was amended on the floor so as to provide "that the acquisition of any land in the Potomac River valley for park purposes shall not debar, or limit, or abridge its use for such works as Congress may in the future authorize for the improvement and the extension of navigation, including the connecting of the upper Potomac River with the Ohio River, or for flood control, or irrigation, or drainage, or for the development of hydro-electric power." Another amendment precludes the construction of a private toll bridge within the confines of the parkway. Still another makes mandatory a free bridge at or near Great Falls.

Objection to the bill was based almost entirely on the proposition to set up a parkway without expressed recognition of the development of the resources of the Potomac for navigation and power, and for the control of floods.

Columbia River Power Reserved

Power permits or licenses on the Columbia River between Grand Coulee dam site and the Canadian border are held up by a resolution (S.J. Res. 130) introduced by Senator Dill and adopted on Jan. 31 after having been held in committee only a week. The effect of this measure is to prevent construction either at Grand Coulee or at Kettle Falls until the Engineer Corps has completed its investigation and has issued its report as to the uses of the stretch of river in question. A preliminary permit was issued to the Washington Power Co. for the latter project in 1921 and an application for license has been pending since 1925. Advocates of the Grand Coulee development, which concerns power and principally irrigation, would build a dam that would drown out part of the head

at Kettle Falls. The apparent intent of the resolution is to prevent either project taking priority until the relative merits have been indicated by army data.

Railway Valuation

Nothing daunted by the Supreme Court's dictum that cost of replacement must be considered in fixing the value of railroad properties for rate-making and recapture purposes, the Interstate Commerce Commission has recommended that Congress should write into the law a method that in principle and practical results is the same as that applied by the commission in the celebrated O'Fallon case. If the commission can prevail upon Congress to accept its recommendation it will have succeeded in establishing, in terms of law, its theory of valuation and at the same time will relieve itself of a bewildering responsibility. The commission's move followed immediately upon a hearing called to consider how the court's precept that cost of reproduction new should be considered as an element of value should be applied. As outlined in a letter addressed by Commissioner Eastman to Senator Couzens, chairman of the Senate interstate commerce committee, up-to-date valuations under the commission's modified method "would be determined by taking the cost of reproduction new at the 1914 unit prices of the property existing on the original valuation date, plus the then value of the lands, adding or subtracting the subsequent net increase or decrease in the property investment account as shown by the accounts when correctly kept, adding further a proper allowance for working capital and deducting the balance standing in the depreciation reserve."

Chicago Pleads Poverty

Arguing that the city has no money to go ahead with the construction required under the schedule of diversion reduction proposed by Special Master Charles Evans Hughes, the city of Chicago, in a brief filed Feb. 3 in exception to the proposed decree of the U. S. Supreme Court, requested a seven-year extension from 1938 to 1945 in the time allowed for completion of its sewage-treatment program. The city claimed that Special Master Hughes had not given consideration to its financial condition in his recommendations and had overlooked "the delays necessarily arising in a municipal corporation raising and providing moneys needed for construction work, because of the requirement that bond issues shall be approved by vote of the people, and because of technicalities necessarily attendant upon providing funds from year to year under budgets which must be adopted subsequent to statutory requirements." Chicago also claimed that the special master had failed to consider the substantial rise in lake levels in recent years, remedying some of the conditions complained of by the Lake states, and making possible granting of a longer period for remedial measures.

Briefs filed by the Lake states in exception to the proposed decree requested more definite and complete limitation of diversion and asked that all costs in the twenty years of litigation be assessed against the city of Chicago and the Sanitary District. Counsel for the Lake states are of the opinion that the wording of the decree limiting diversion to stated amounts "in addition to domestic pumpage" is insufficient, inasmuch as it would not prevent Chicago from increasing its pumpage capacity to the point where it was diverting just as much water by a different route.

Society Calendar

AMERICAN CONCRETE INSTITUTE, Detroit; annual convention, New Orleans, La., Feb. 11-13.

AMERICAN RAILWAY ENGINEERING ASSOCIATION, Chicago; annual meeting, Chicago, Ill., March 11-13.

AMERICAN SOCIETY OF CIVIL ENGINEERS, New York; spring meeting, Sacramento, Calif., April 23-24.

AMERICAN WATER WORKS ASSOCIATION, New York; annual meeting, St. Louis, Mo., June 2-6.

ASSOCIATION OF HIGHWAY OFFICIALS OF NORTH ATLANTIC STATES, Trenton; annual convention, Syracuse, N. Y., Feb. 19-21.

ENGINEERING INSTITUTE OF CANADA, Montreal; annual convention, Ottawa, Ont., Feb. 12-14.

CEMENT GUN CONTRACTORS ASSOCIATION will hold its annual convention Feb. 17-19 at Chicago, Ill.

ENGINEERING SOCIETY OF WISCONSIN will hold its 22nd annual convention at Madison, Feb. 20-21, with aspecial session for surveyors on Feb. 19. R. S. Owen, Madison, is secretary.

HIGHWAY ENGINEERS ASSOCIATION OF MISSOURI will meet Feb. 18-20 at Kansas City, Mo.

KENTUCKY - TENNESSEE SECTION, American Water Works Association, at its annual meeting Jan. 23-25 at Lexington, Ky., elected A. E. Clark, associate engineer, Tennessee State Department of Health, chairman and Howard K. Bell, consulting engineer, of Lexington, vice-chairman. F. C. Dugan, chief engineer of the Kentucky State Department of Health, was chosen secretary. The section will be represented in the parent society by A. F. Porzellius, superintendent of the City Water Co., Chattanooga, Tenn.

MATERIALS HANDLING will be the subject of a special meeting of the American Society of Mechanical Engineers to be held March 5-7 at Chicago in conjunction with the National Industrial Exposition of material-handling equipment.

MINNESOTA FEDERATION OF ARCHITECTURAL AND ENGINEERING SOCIETIES will hold its annual convention Feb. 14-15 at Duluth.

NATIONAL DRAINAGE CONGRESS will hold its nineteenth annual session at St. Louis, Mo., Feb. 19-21.

NEW ENGLAND WATER WORKS ASSOCIATION at its February meeting, to be held in Boston Feb. 12, will be addressed by Allen Hazen, consulting engineer, New York City, and Frank E. Hale, director of laboratories for the New York City Department of Water Supply, Gas and Electricity.

PENNSYLVANIA ASSOCIATION OF PLANNING COMMISSIONS will hold its annual conference at Easton Feb. 18-19.

ROCKY MOUNTAIN SECTION, American Water Works Association, will hold its annual meeting Feb. 13-14 at Denver. Dana E. Kepner, Denver, is secretary.

WESTERN WASHINGTON SECTION, American Society of Civil Engineers, held its annual dinner meeting at the Engineers' Club, Seattle, on Jan. 27. The principal speaker was Commander W. Dixon Hopcraft of the British Navy, retired. The following officers were elected for the year 1930: president, J. R. West, chief engineer, Port of Seattle Commission; vice-president, E. L. Strandberg, structural engineer; secretary-treasurer, Thomas D. Hunt, King County engineer (re-elected).

Obituary

ALONZO ROBERT MULLIN, chief engineer of the Seattle (Wash.) municipal light department's Lake Union steam plant, died suddenly on Jan. 17 following a heart attack.

ALBERT T. SPENCER, general superintendent of construction and maintenance of the Montreal Tramway Co., died in Montreal on Jan. 26 aged 53. He had been assistant engineer of the Montreal Park & Island Railway and assistant engineer of way and structures of the Montreal Tramways Co. As chairman of the standing committee on way and structures of the American Electric Railway Engineering Association, he conducted a study on the use of alloy steels in special trackwork.

E. L. SLEEPER, for the past fifteen years personal representative of G. J. Kuhrts, president and general manager of the Los Angeles Railway Corporation, died suddenly Jan. 18, following an acute heart attack. Mr. Sleeper was a native of Boston, Mass., and a civil engineer. He had been employed on a number of large engineering projects in the East before going to southern California in 1908. From 1910 to 1913 he was city engineer of Pomona, Calif. In 1913 he became superintendent of construction in the outer harbor at San Pedro, which position he held until 1913, when he joined the Los Angeles Railway Corporation.

Costs and Contracts

E. N.-R. Index Numbers

Cost			Volume		
Feb. 1, 1930	**206.46**		**January, 1930**	**199**
Jan. 1, 1930	208.96		December, 1929	166
Feb. 1, 1929	210.40		January, 1929	325
Average, 1929	207.02		Average, 1929	317
Average, 1928	206.78		Average, 1928	287
1913	100.00		1913	100

This Week's Contracts

Heavy construction contracts, reported by *Engineering News-Record* in the week of Feb. 6, with some comparisons, total as follows:

(In Thousands of Dollars)

	Feb. 6, 1930	Jan. 30, 1930	Feb. 7 1929
Buildings:			
Industrial	$1,532	$7,540	$25,993
Commercial	7,900	18,852	55,524
Streets and roads	8,458	7,139	3,124
Other eng. constr.	10,616	15,751	32,097
Total	$28,506	$49,282	$116,738
Total, all classes, Jan. 1 to Feb. 6:			
1930			$267,442
1929			513,571

Current Prices of Construction Materials

Price advances since last month are indicated by **heavy type**; declines by *italics*

Building Materials

PORTLAND CEMENT—Prices per barrel, *without charge for bags*, cash discount not deducted. Prices marked f.o.b. are manufacturers'; others are delivered by truck to contractors:

	Feb. 6, 1930	One Month Ago	One Year Ago
Atlanta	$2.35	$2.35	$2.25
Baltimore	2.40	2.40	2.65
Birmingham	2.40	2.40	2.60
Boston	**2.65**	2.28	2.45
Cedar Rapids (f. o. b.)	2.04	2.04	2.24
Chicago (f. o. b.)	1.85	1.85	2.05
Cincinnati (f. o. b.)	1.92	1.92	2.22
Cleveland (f. o. b.)	1.94	1.94	2.24
Dallas	2.15	2.15	2.15
Davenport (f. o. b.)	2.04	2.04	2.24
Denver	2.61	2.61	2.55
Detroit (f. o. b.)	1.95	1.95	1.95
Duluth (f. o. b.)	1.94	1.94	2.04
Indianapolis, (f. o. b.)	1.89	1.89	2.09
Jersey City	2.60	2.60	2.25@2.40
Kansas City, Mo.	2.65	2.65	2.40
Los Angeles	2.42	2.42	2.66
Milwaukee (f. o. b.)	2.00	2.00	2.20
Minneapolis (f. o. b.)	2.02	2.02	2.22
Montreal (f. o. b.)	2.05	2.05	1.41
New Orleans	2.65	2.65	2.65
New York	2.30	2.30	2.25@2.35
Peoria (f. o. b.)	2.02	2.02	2.22
Philadelphia	2.10	2.10	2.40
Pittsburgh (f. o. b.)	1.85	1.85	2.05
St. Louis	2.10	2.10	2.45
St. Paul (f. o. b.)	2.02	2.02	2.22
San Francisco	2.54	2.54	2.41
Seattle	2.70	2.70	2.70
Toledo (f. o. b.)	2.03	2.03	2.20

Current mill-prices per barrel, in carloads, without bags, f.o.b.:

Alpena, Mich.	$1.65	Limedale, Ind.	$1.60
Buffington, Ind.	1.60	Mason City, Ia.	**1.85**
Hannibal, Mo.	1.80	Norfolk, Va.	1.90
Houston, Tex.	1.95	North Birmingham, Ala.	1.70
Hudson, N. Y.	1.85	Richard City, Tenn.	2.05
Ironton, Ohio	1.50	Steelton, Minn.	**1.85**
Iola, Kan.	**1.85**	Universal, Pa.	1.60
La Salle, Ill.	1.70	Wyandotte, Mich.	1.70
Lehigh Valley District	1.75		

SAND AND GRAVEL—Per cu.yd., delivered by dealers. Weight of sand, 1½ tons per cu.yd.; gravel, 1½ tons per cu.yd., unless otherwise specified in pounds:

	Gravel		Sand
	1½ In.	¾ In.	
Atlanta, per ton	**$3.00**	**$3.00**	**$2.25**
Baltimore, per ton	2.40	2.60	1.70
Birmingham (2,600 lb. per cu.yd.)	3.00	3.00	2.65
Boston, per ton	1.90	1.90	1.25
Chicago	1.90	1.90	1.80
Cincinnati, per ton	1.65	1.65	1.40
Cleveland (3,000 lb.) (2,700 lb.)	2.60	2.60	2.50
Dallas	2.60	2.60	2.60
Denver (2,700 lb. per cu.yd.)	1.80	1.80	1.30
Detroit (2,600 lb. per cu.yd.)	3.25	3.25	2.75
Kansas City, Mo.	1.85	1.85	1.85
Los Angeles, per ton	2.15	2.15	1.30
Minneapolis (2,800 lb.) (3,000 lb.)	2.40	2.40	1.10
Montreal, per ton	1.25	1.25	1.25
New Orleans (2,700 lb.) (2,500 lb.)	3.75	3.75	2.75
New York	3.40	3.40	2.15
Philadelphia, per ton	2.30@3.15	2.30@3.15	1.50@2.31
Pittsburgh, per ton	2.20	2.20	2.40
St. Louis, per ton	2.35	2.25	2.00
San Francisco, per ton	1.75	1.75	1.75
Seattle (3,200 lb.) (2,850 lb.)	1.75	1.75	1.75

Note: New York gravel weighs 2,800@3,000 lb. and sand, 2,700 lb.

CRUSHED STONE—Per cu.yd., delivered by dealers. Weight, 1½ tons per cu. yd., unless otherwise specified in pounds:

	1½ In.	¾ In.
Atlanta, per ton	$2.65	$2.65
Baltimore, per ton	2.75	2.85
Birmingham, Limestone	3.00	3.25
Boston, per ton	*2.10*	*2.10*
Chicago, Limestone (2,500 lb. per cu.yd.)	1.90	1.90
Cincinnati, per ton	2.25	2.25
Cleveland, per ton (2,500 lb. per cu.yd.)	2.70	2.70
Dallas (2,500 lb. per cu.yd.)	3.25	3.40
Denver, Granite (2,700 lb. per cu.yd.)	2.50	2.50
Detroit, Limestone, per ton (2,500 lb. per cu.yd.)	3.00	3.00
Kansas City, Limestone	1.85	1.85
Los Angeles, per ton	2.15	2.15
Minneapolis, Limestone (2,600 lb. per cu.yd.)	2.40	2.40
Montreal, per ton	1.90	2.10
New York, Limestone	3.40	3.40
Philadelphia, Limestone, per ton	2.30@3.15	2.30@3.15
Pittsburgh, per ton	2.75	2.75
St. Louis, per ton, (2,400 lb. per cu.yd.)	1.90	1.90
San Francisco, Trap rock, per ton	1.65	1.65
Seattle, (2,700 lb. per cu.yd.)	1.90	1.90

CRUSHED SLAG—Manufacturers' quotations on crushed slag in carloads, per net ton, at plant:

	1½-In.	¾-In.	Roofing	Sand
Birmingham, Ala.	$0.90	$1.15	$2.05	$0.55
Buffalo District	1.25	1.35	2.25	1.25
Cleveland, Ohio	**1.35**	**1.35**	.....	.90
Eastern Pa. and Northern N. J.	1.25	1.25	2.00	1.25
Toledo, Ohio	1.25	1.25	1.50	1.25
Western Pennsylvania	.....	.....	.....	.....
Youngstown District	1.30	1.40	2.00	1.30

HOLLOW TILE—Building tile per block, delivered by dealers to contractors n lots of 2,000 pieces or over:

	4x12x12	6x12x12	8x12x12	10x12x12	12x12x12
Atlanta	$0.072	$0.099	$0.135	$0.181	$0.202
Baltimore	.105	.....	.20	.....	.26
Birmingham	.09	.127	.174	.218	.261
Boston	.086	.113	.155	.20	.26
Chicago	.076	.104	.142	.182	.202
Cincinnati	.066	.09	.125	.16	.18
Cleveland	.064	.088	.128	.171	.19
Dallas	**.096**	*.122*	*.18*	**.275**	*.296*
Denver	.0975	.135	.175	.2125	.25
Detroit	.098	.135	.184	.24	.265
Kansas City	.0525	.077	.184	.24	.265
Los Angeles	.085	.122	.175	.232	.285
Minneapolis	.0611	.081	.10605	.1302	.1737
Montreal	.12*	.....	.22†	.....	.....
New Orleans	.086	.118	.16	.212	.256
New York	.0864	.1296	.162	.....	.....
Perth Amboy, N.J. (f.o.b.)	.....	.....	.....	.2388	.2956
Philadelphia	.105	.14	.215	.28	.34
Pittsburgh	.068	.....	.1175	.....	.1726
St. Louis	.078	.104	.145	.175	.21
San Francisco	.108	.156	.255	.....	.....
Seattle	.085	.115	.18	.....	.....

*4x4x12. †8x8x12.

BRICK—Prices delivered by dealers per thousand, are as follows:

		Paving	F.O.B.
	Common	3x8½x4-in.	3½x8½x4-in.
Atlanta	**$14.50**	**$36.00***	**$42.00†**
Baltimore	13.00	40.00	46.00
Birmingham	15.00	30.00*	34.00†
Boston	16.00	43.00	47.00
Chicago	12.00	42.00	45.00
Cincinnati	18.00	40.00	45.00
Cleveland	14@16	33.00	36.00
Dallas	13.50	30.00	.....
Denver	11.00	.....	.....
Detroit	*15.00*	*33.50*	*36.50*
Kansas City	14.00	.....	.....
Los Angeles	*12.00*	.....	.....
Minneapolis	12.75	.....	.....
Montreal	20.00	.....	.....
New Orleans	16.50	38.00*	45.00
New York	14@15	45.00	50.00
Philadelphia	16.00	40.00	46.00
Pittsburgh	16.00	40.50	45.00
St. Louis	**13.50**	**38.00**	40.00
San Francisco	14.50	45.00*	.....
Seattle	14.00	50.00	55.00

*2½x8½x4 in. †3x8½x4.

LIME—Prices delivered by dealers to job:

	Hydrated, per Ton		Lump, per Barrel	
	Finishing	Common	Finishing	Common
Atlanta	$21.00	**$15.00**	.....	.....
Baltimore	22.00	14.00	$2.55†	.....
Birmingham	22.00	16.00	3.00†	$2.00†
Boston	22.00	15.00	4.00*	3.00*
Chicago	18.00	14.00	18.00‡	1.35†
Cincinnati	15.30	12.70	.....	.....
Cleveland	16.00	12.00	2.50†	2.50†
Dallas	20.00	.....	.....	18.00‡
Denver	32.00	23.75	3.80*	3.00*
Detroit	19.20	14.80	2.20†	2.20†
Kansas City	16.00	12.50	2.75†	2.40†
Los Angeles	25.00	18.00	2.85†	17.00‡
Minneapolis	25.50	21.00	.....	1.70†
Montreal	19.75	.....	.....	15.00‡
New Orleans	.....	.....	2.60†	1.60†
New York	21@23	14@15	4.10@4.20	3.15@3.25*
Philadelphia	22.00	15.00	.....	.....
Pittsburgh	21.00	19.00	2.50†	.....
St. Louis	24.00	18.00	2.75†	15.00‡
San Francisco	27.50	20.00	2.00†	1.60†
Seattle, paper sacks	36.00	24.00	.....	2.80†

*Per 280-lb. bbl. (net). †Per 180-lb. (net). ‡Per ton.

CONCRETE BLOCKS—Manufacturers' quotations on standard, 8x8x16-in., hollow, delivered to job, each:

Boston	*$0.20*	Minneapolis	$0.15
Brooklyn and Queens	.12@.14	New Orleans	.22
Cleveland	.16@.17	Philadelphia	.18@.25
Denver	.22	Pittsburgh	.20
Detroit	.15	St. Louis	.18

SLATE—Roofing, f.o.b., quarry, Bangor, Pa., net, per square:

No. 1 Clear	$9.45@$13.05
No. 1 Ribbon	8.10@ 9.23
Medium Clear	8.55@ 10.13

Road and Paving Materials

PAVING STONE—Carloads or cargo lots of granite blocks, 4x8x4-in., dressed, f.o.b:

Atlanta	$3.00 per sq.yd
Baltimore	3.00 per sq.yd.
Boston	135.00 per M.
Chicago, 5 in.	3.25@3.90 per sq.yd.
Cincinnati	110.00 per M.
Cleveland	115@120 per M
Detroit, 5 in.	3.00 per sq.yd.
Kansas City	3.00 per sq.yd.
Minneapolis, 4½x8x5 in	2.80 per sq.yd.
Montreal	104.75 per M.
New Orleans	2.80 per sq.yd.
New York, 5 in., Grade 1, 30 blocks per sq.yd	150.00 per M.
Philadelphia	125.00 per M.
St. Louis, 4x5x8 to 12 in.	3.50 per sq.yd

Current Prices of Construction Materials

Road and Paving Materials—Continued

WOOD-BLOCK PAVING—Prices, f.o.b., in carloads:

	Size of Block	Treatment	Per Sq.Yd.
Atlanta	3½	16	$2 25
Boston	3½	16	2 25
Chicago	3½	12	2 10
Cincinnati	3½	16	2.35
Dallas	3½	18	3 90
Kansas City	3½	16	2.75
Minneapolis	3½	16	2 75
Montreal	4	16	4 50
New Orleans	3½	16	*2 50*
New York	3½	16	2 70
St. Louis	3½	16	2 25

FLAGGING—Alongside dock, New York: Manhattan and Bronx, 4 ft. wide, 24c. per sq.ft.; Queens, 5 ft wide, 26c. per sq.ft.

CURBING—*New York*: Bluestone, f.o.b. barge, 5x16 in., rough, 90c. per lin. ft., cutting charges extra. *Birmingham*: Limestone, 5x18-in., f.o.b., $1.05 per lin.ft. *St. Louis*: Class "B" straight, 5x16 in., f.o.b., $1.00 per lin.ft.; roundings, $1.50 per lin.ft.

ASPHALT—Manufacturers' quotations per ton in packages (350-lb. bbls. or 425-lb. drums); also in tank-car lots, f.o.b. points listed:

	Package	Tank-car
Atlanta (Mexican)	$20 40	$16 40
Baltimore (Standard Oil, f.o.b. refinery)	21.75	17 75
Birmingham (Mexican)	27.00	23.00
Boston (Mexican)	23 50	18.00
Chicago (Texas)	23 50	19 30
Cincinnati (Kentucky Rock)		12 30
Cleveland	24.00	20.00
Dallas (Texas)	*24.35*	
Denver (California)	35.00	
Detroit (Mexican)	19.72	15 69
Kansas City, Mo. (Texas)	35.00	28.00
Los Angeles ("D" Grade, Calif., f.o.b., El Segundo)	18.00	12.00
Maurer, N. J. (Bermudes)	30.00	
Maurer, N. J. (Trinidad)	25.00	
Minneapolis, (Stanolind, f.o.b., Twin Cities)	24 10	19 10
Montreal (Imperial)	28.00	21 50
New Orleans (Texas)	24.00	21.00
New York (Texas)	22 50	18.50
Philadelphia (Mexican)	18.00	15.00
Pittsburgh (Standard Oil)	24@26	14@18
St. Louis (Mexican)	**22 40**	**18 40**
San Francisco, (f.o.b. refinery, Oleum, Calif.)	18.00	12.00
Seattle, ("D" grade, Calif., f.o.b. Richmond)	18.00	12.00

ROAD OILS—Manufacturers' quotations, f.o.b., in tank cars, 8,000 gal. minimum, per gal.:

Birmingham, 40@50% asphalt	$0.0525
Birmingham, 50@60% asphalt	.0525
Dallas, 40@50% asphalt	**.055**
Dallas, 50@60% asphalt	**.055**
New York, 40@50% asphalt (at terminal)	.05
New York, 50@60% asphalt (at terminal)	.05
St. Louis, 40@50% asphalt	**.015**
St. Louis, 50@60% asphalt	**.045**

Iron and Steel

PIG IRON—Producers' quotations, per gross ton, f.o.b.:

Birmingham, No. 2 fdry., silicon 1.75@2.25	*$15.00*
Pittsburgh, basic, incl. freight ($1.76) from Valley	20.26

STRUCTURAL STEEL—Manufacturers' and dealers' quotations per 100 lb.:

	Shapes, 3 to 15-In.	Plates, ¼-In
Birmingham, large mill lots, f.o.b.	$2.15	$2.15
Chicago, warehouse, delivered	3.10	3.10
Cleveland, warehouse, delivered	3 00	3 00
Dallas, warehouse, delivered	**4.50**	**4 50**
New York, warehouse, delivered, up to 3,999 lb.	3.30	3.30
Pittsburgh, large mill lots, f.o.b.	*1.80*	*1.80*
St. Louis, warehouse, delivered	3.25	3.25
San Francisco, warehouse, delivered	3 40	3.40

BARS, CONCRETE REINFORCING—Manufacturers' and dealers' quotations on bars rolled from billets, per 100 lb. for ½-in.:

Birmingham, large mill lots, f.o.b.	$2.15
Chicago, warehouse, delivered	2.15@3.00
Cleveland, warehouse, delivered	2.25@2.44
Dallas, warehouse, delivered	**3.75**
New York, warehouse, delivered, over 5 tons	2.70
Pittsburgh, large mill lots, stock lengths, f.o.b.	2.00
St. Louis, warehouse, delivered	3.15
San Francisco, warehouse, delivered	2.25

EXPANDED METAL LATH—Per 100 sq.yd., painted, delivered to job, in less-than-carload lots:

Lb. per Sq. Yd.	New York	Birmingham	Chicago	St. Louis	Dallas	San Francisco
2.2	$18.50	$22.00	$20.50	*$20.50*	$21.50	$21.50
2.5	19.50	23.00	21.50	*21.50*	24.00	22.50
3.0	21.00	25.00	23.00	*23.00*	26.00	25.00
3.4	22.00	26.50	24.00	*24.00*	30.00	27.00

WIRE REINFORCEMENT FOR CONCRETE—Manufacturers' quotations per 100 sq.ft. in carloads at mills; and delivered by dealers, in lots of 10,000 sq.ft. or over; plain 4 in. by 4 in. mesh:

Style Number	Weight in Pounds per 100 sq.ft.	Pittsburgh Mill	Chicago District Mill	Warehouse Delivery: New York	St. Louis	Dallas	San Francisco
032	22	$0.99	$1.01	$1.39	$1.45	$1.13	$1.22
049	28	1.26	1.29	1.76	1.80	1.38	1.55
068	35	1.54	1.58	2.18	2.25	1.67	1.91
093	40	1.98	2.03	2.79	2.95	2.00	2.46
126	57	2.45	2.51	3.45	3.55	2.55	3.03
153	68	2.92	2.99	4.13	4.25	3.15	....
180	78	3.35	3.43	4.73	4.85	3.47	....

STEEL SHEETS—Manufacturers' and dealers' quotations per 100 lb., base:

	Blue Annealed No. 10 *	Black No. 24	Galvanized No. 24
Chicago, warehouse, delivered	$3.35	$4.05	$4.90
Cleveland, warehouse, delivered	3.30	*4.75*	*4.50*
New York, warehouse, delivered	3.90†	3.90	**4.75**
Pittsburgh, large mill lots, f.o.b.	2.10@2.20	*2.55*@2.75	*3.40@3.50*
St. Louis, warehouse, delivered	3.45	4.25	5.10
San Francisco, warehouse, delivered	4.00	5.00	5.40

*Light plates †Up to 3,999 lb.

WIRE ROPE—Discounts from manufacturers' list price on regular grades of bright and galvanized, Eastern Territory, New York, and East of Missouri River

	Base
Cast steel round strand rope	20%
Galvanized iron rigging and guy rope (add to list)	12½%
Galvanized steel rigging and guy rope	7½%
Plow steel round strand rope	35%
Round strand iron and iron tiller	5%
"Special Steel" and extra strength cast steel, round strand rope	27½%

Discount 5 points less than discount for Eastern territory: California, Oregon, Nevada, Washington, Wyoming, New Mexico, Colorado, North Dakota, Nebraska, Kansas, Oklahoma and Texas. Discount 10 points less than discount for Eastern territory: Arizona, Montana, Idaho and Utah.

RIVETS—Manufacturers' and dealers' quotations on structural rivets, round-head, ½-in., full kegs, per 100 lb.:

Chicago, warehouse, delivered	$4.00
Dallas, warehouse, delivered	**5.50**
New York, warehouse, delivered	4.50*
Pittsburgh, large mill lots, f.o.b.	3.10
St. Louis, warehouse, delivered	4.15
San Francisco, warehouse, delivered	5.00
Seattle, warehouse, delivered	4.25

*This price is for full kegs; broken kegs are $6.00 per 100 lb.

STEEL SHEETPILING—The manufacturers' base price, f.o.b., Pittsburgh, for large mill lots is $2.25 per 100 lb.

TERNE PLATE—I C, 8-lb. coating, 20x28-in., f.o.b., Pittsburgh mill:

Per package	$10.70

SHIP SPIKES—Per 100 lb., black, from dealers' warehouse stocks; galvanized are about $1.75 per 100 lb. higher:

	½-In.	⅝-In.	¾-In.
San Francisco	$5.55	$5.10	$4.95
Seattle	7.75	5.65	5.50

Pittsburgh mill base in lots of 200 kegs or more, $3.00 per 100 lb.

WIRE NAILS—Per 100 lb. keg, base, delivered from warehouse stocks; also Pittsburgh mill base:

Pittsburgh Mill	Birmingham	Chicago	St. Louis	Dallas	San Francisco	Montreal
$2.30@*$2.40*	$3.30	$2.75	$2.95	$3.75	$3.25	$4.95

SCRAP—The prices following are, f.o.b., per ton, paid by dealers:

	New York Per Gross Ton	Chicago Per Gross Ton	Detroit Per Gross Ton
No. 1 railroad wrought	$11.50@$12 50	$13.00@$13.50	$12.50@$13.00
Stove plate	8.00@ 8.50	11.00@ 11.50	10.00
No. 1 machinery cast	10.85	14.50@ 15.00	12.00*
Machine shop turnings	7.00@ 7.50	7.00@ 7.50	8.25
Cast borings	7.00@ 7.50	9.00@ 9.50	9.50
Railroad malleable	12.50@ 13.00	16.00@ 16.50	13.00
Re-rolling rails	10.50@ 11.00	15.00@ 15.50	13.00
Re-laying rails, 56@60 lb.	23.00@ 24.00	21.00@ 24.00	
Heavy melting steel, No. 1	10.50@ 11.35	12.50@ 13.00	**12.25**
Iron and steel pipe	9.25@ 9.75	9.00@ 9.50	*9.50*@10.00

*Net ton.

FREIGHT RATES—On finished steel products in the Pittsburgh district, including plates, structural shapes, merchant-steel bars, pipe fittings, plain and galvanized wire nails, rivets, spikes, bolts, flat sheets (except planished), chains, etc., the following freight rates are effective in cents per 100 lb., in carload lots of 36,000 lb. or 18 tons:

Atlanta	$0.58	Detroit	$0.29
Baltimore	.31	Kansas City	.71†
Birmingham	.58	New Orleans	.67
Boston	.365	New York	.34
Buffalo	.265	Pacific Coast (all rail)	1.15*
Chicago	.34	Philadelphia	.32
Cincinnati	.27	St. Louis	.405
Cleveland	.19	St. Paul	.60
Denver	1.15*		

*Minimum weight on structurals, 60,000 lb. †Except iron or steel pipe and fittings.

Railway Materials and Supplies

STEEL RAILS—Manufacturers' quotations per gross ton, f.o.b., for large mill lots:

	Pittsburgh	Birmingham	Chicago
Standard openhearth rails	$43.00	$43.00	$43.00
Light rails, 25 to 45 lb.	36.00	34@36	34@36
Re-rolled rails	34.00	34@36	34@36

RAILWAY TIES—For fair-sized orders, f.o.b., the following prices bold:

		6 In. x 8 In. by 8 Ft.	7 In. x 9 In. by 8½ Ft.
New York	Long-leaf sap pine, untreated	$1.10	$1.30
	Creosoted—prices on application.		
Birmingham	White oak, creosoted	1.52	1.75
	Southern pine, creosoted	1.25	1.60
Chicago	White oak, untreated	1.40	1.78
	Oak, empty cell, creosoted	1.80	2.40
	Oak, zinc treated	1.60	2.10
	Southern pine, creosoted	1.60	2.10
St. Louis	White oak, untreated	**1.25**	*1.60*
	Red oak, creosoted	**1.65**	*2.00*
San Francisco	Sap pine or cypress, untreated	**1.00**	1.35
	Douglas fir, green, untreated	87½	1.21
	Douglas fir, empty cell, creosoted	1.60	2.10
Montreal	Birch or maple, untreated	.75@1.25	.75@1.25
	Birch or maple, creosoted	1.30@1.30	1.50@1.40